Vol. 2 OCTOBER, 1919 No. 10

Journal

—OF THE—

American Ceramic Society

A Monthly Journal devoted to the Arts and Sciences Related to the Silicate Industries.

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Published Monthly by the
AMERICAN CERAMIC SOCIETY

Publication Office
211 Church St., Easton, Pa.

Editorial Office
Rutgers College, New Brunswick, N. J.

SIX DOLLARS PER YEAR (Foreign Postage Additional) *SINGLE NUMBERS, SIXTY CENTS*

Entered as second-class matter, July 15, 1918, at the post office at Easton, Pa., under the Act of March 3, 1879.

Acceptance for mailing at special rate of postage provided for in section 1103, Act of October 3, 1917, authorized August 16, 1918.

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JOURNAL
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AMERICAN CERAMIC SOCIETY

A monthly journal devoted to the arts and sciences related to the silicate industries.

Vol. 2 **October, 1919** **No. 10**

EDITORIALS.

CERAMIC PRODUCTS AT THE FIFTH NATIONAL EXPOSITION OF CHEMICAL INDUSTRIES, CHICAGO, ILL., SEPT. 22–27, 1919.

The extensive and varied display of ceramic products at the Exposition demonstrated how essential the silicate industry is to chemical work. There were only a few products not previously exhibited, for the American manufacturer for the past year or so has been supplying practically everything along this line that is needed. The exhibit showed that they have been consolidating their position by extending the application of their wares, standardizing on designs and shapes and improving the quality. In some cases the increased size and intricacy of design now being made is a very decided advance in the art.

The ceramic exhibits were more numerous than those of last year. There were two exhibits on Insulating Materials, five on Chemical Stoneware, four on Enameled Ware, three on Refractories, five on Chemical Porcelain, two on Optical Glass, and seven on Chemical Glassware.

Chemical Stoneware.

New designs and shapes of acid-proof stoneware have been required in the manufacture of dyes, acids and other chemical products. The success with which the manufacturers have met the problems of shaping and molding the ware was shown by the exhibits of Maurice A. Knight, General Ceramics Company, B. Mifflin Hood Brick Company, G. H. Elmore, and the United

States Stoneware Company. Spiral coils several feet high, sharply threaded spigots, large tanks, ground valve and valve seats, equal to those of polished steel, are examples of the difficult shapes molded and the quality of the finished product. When hit with a hammer, this ware shows the strength and "ring" of cast iron.

Most of the products are glazed, although this is a choice with the buyer, as the ware is thoroughly vitrified and the acid-proof qualities are not dependent upon the glaze. Twelve different bodies are used by manufacturers to meet the special requirements in use to which the ware is put. Attempts are being made by manufacturers to standardize shapes and sizes of ware, where possible, which should be beneficial to the buyer as well as to the manufacturer of stoneware.

Enameled Wares.

Enameled wares formed a good share of the ceramic exhibits, especially acid-proof cast iron products. The exhibitors were: The Pfaudler Company, The Elyria Enameled Products Company, Vitreous Enameling Company, and J. L. Mott Iron Works. This branch of the ceramic industry has extended its products into fields where the contact of materials with metal is harmful to the finished product, such as in the manufacture of candy and dyes. There is hardly an industry where the operations of mixing and evaporating are used that is not adopting this ware. As in the stoneware industry, advancements have been made largely in the increased size of the product and its shape. However, this advancement deserves much credit.

Refractories.

Refractory products and materials were shown by the Carborundum Company, The Norton Company and The Denver Fire Clay Company.

The exhibit of The Carborundum Company included carbofrax and refrax brick, tile, muffles, tubes, carborundum refractory-cement, carbofrax saggers, fire sand, silicon metal, carborundum and aloxite wheels. The carbofrax saggers are a new

product. They have a high heat conductivity and a low coefficient of expansion, thus giving them a life many times greater than that of ordinary saggers. Two saggers on exhibition were said to have stood 211 burns to cone 13 under a load of 45 pounds. Two grades are being made, one for use above and the other below cone 12. To prevent discoloration of the ware burned in them, glazing is resorted to.

The Norton Company exhibit showed the alundum and crystolon refractories, laboratory ware, and refractory cement. Samples of ignition capsules, combustion tubes, filtering cones, pyrometer tubes and alundum and crystolon linings for electric furnaces made the exhibit an interesting one. A sample of electrically fused or sintered magnesia was worthy of notice. This product is new and has not yet been fully developed. Further investigations along this line will undoubtedly develop a new ware useful in chemical work.

The Denver Fire Clay Company had a very fine display of highly refractory fire-clay crucible of all sizes and a good line of cupels and scorifiers.

Chemical Porcelain.

Chemical porcelain was exhibited by The Coors Porcelain Company, Ohio Pottery Company and The Guernsey Earthenware Company. Each had a very complete display of porcelain crucibles, filter plates, casseroles, combustion capsules, evaporating dishes, concentric rings, filter rings, dye pots, funnels, desiccator plates, and many other forms used in chemical laboratories. The Coors Company showed a novel Bunsen burner made of glazed porcelain. Large evaporating dishes, both shallow and deep, in diameters up to twenty inches, showed successful advances along this line. The standards of workmanship and quality of ware were apparent advances made in porcelain manufacture.

Optical Glass.

There were two exhibits of optical glass, one by the Bausch and Lomb Optical Glass Company and the other by the Macbeth-Evans Company. Great advances have been made, due to re-

strictions in trade during the war. Optical glass has not only been made in the United States and from our own raw materials but of an excellent quality. The Bausch and Lomb Company displayed samples of their glass known as light flint No. 2, dense flint, extra dense flint, and boro-silicate crown, together with improved types of colorimeters, and refractometers. The Macbeth-Evans Company featured a large lighthouse lens made of their optical glass, together with a small exhibit of their well-known glassware.

Chemical Glassware.

The chemical glassware industry showed a great advancement in the quality of their products and in the manufacture of various shapes. Many manufacturers have brought their product up to the United States Bureau of Standards quality during the past few years. The exhibits have conclusively proven that the lack of mechanical skill in the making of various shapes of blown glassware is rapidly decreasing. Pieces of blown glassware, in the most intricate and accurately made forms, were a miracle to the ceramist in the way of shaping and forming the ware.

The Whitall-Tatum Company booth had a very effective display of their well and favorably known "non-sol" chemical glassware. The feature of the display was a 250 cc. "non-sol" beaker from which 220,000 cc. of distilled water had been driven off by boiling during a total of 1450 working hours.

The glass exhibit of the Corning Glass Works was very extensive, including pyrex glass for laboratory apparatus and baking dishes, chemical glass and laboratory apparatus. One of the features of the exhibit was a piece of square tubing. Colored glass tubing for various purposes formed another interesting portion of the display to the observer.

Booths of dealers in chemical glassware and porcelain were held by The Central Scientific Company, The Hanovia Chemical and Manufacturing Company, Eimer and Amend, Scientific Materials Company, E. H. Sargent and Company and Schaar and Company. The display of Eimer and Amend was of great interest as their work marked some new designs in glassware, together with

many pieces of delicately blown and ground ware. Many pieces of glassware were found to have been standardized according to shapes and sizes, bringing into this field a long-felt want, both to the user and to the manufacturer. Quartz-glass products, as shown by the Hanovia Chemical and Manufacturing Company, indicated advancements in workmanship as well as in increased size of ware. A glass blower, with the Central Scientific Company exhibit, attracted a great deal of attention as he shaped bulbs, pipettes, and other pieces of glassware.

The Thermal Syndicate Company display showed advances in "vitreosil" products for both the plant and the laboratory. As "vitreosil" is unaffected by the usual mineral acids or by sudden or extreme changes in temperature, its use has been extended to the manufacture of small chemical ware such as crucibles and evaporating dishes. Tubes of "vitreosil" ranging from $^{7}/_{16}''$ to $4^{1}/_{2}''$ diameter and 10 feet long were a feature of the exhibit.

Heat-Insulating Materials.

Very interesting exhibits were shown by the Celite Company and the Armstrong Cork Company on heat insulation. The Celite Company presented their product "Sil-O-Cel," in powdered and block form, one of the new features being a block three feet long which will broaden the field of use for this material. The Armstrong Cork Company featured their well-known "Nonpareil" brick. Both exhibitors had small models of kilns and furnaces, showing the application of their product and they also had electric furnaces in operation which demonstrated the superiority of their products over standard fire brick as heat-insulating materials.

ORIGINAL PAPERS AND DISCUSSIONS

THE CAUSE AND CONTROL OF "BLISTERING" IN SHEET-STEEL ENAMELING.

By Chester Treischel.

Introduction.

Every enameler is familiar with the defect known as "blistering," either the type evidenced by a separation of the enamel from the iron or with that one evidenced by a splitting apart of the steel sheet. The present investigation deals only with the latter of the two types. Blisters of this sort occur as a rule in "nests" which are merely aggregations of small blisters. They also seem to occur in parallel rows or striations, probably in the direction of rolling of the sheet, these points being clearly shown in the photographs. This form of blistering, because of its inherent peculiarity of manifesting itself when conditions in the plant are normal, has been the source of much worry to the men in charge, and it is toward determining the cause of and effecting a control over this defect, that this research has been directed.

It is well known that steel and iron absorb hydrogen with great avidity and that in so doing the properties of the metals are markedly altered. When iron is pickeled in acid, either hydrochloric or sulphuric, hydrogen is of course evolved. Enormous quantities of the gas are absorbed by the metal, but what is less well known is that only a part of the hydrogen can be expelled by heating the metal to 1000° C. With the aid of a vacuum it is possible to partially remove the gas at atmospheric temperatures. This fact has been demonstrated by Mr. S. P. Sweetzer, of the General Electric Co. Research Laboratory.

For sometime past it has been known that hydrogen can be

made to pass through comparatively thick walls of iron. By having a hollow vessel as cathode in an electrolytic cell, Dr. I. Langmuir succeeded in collecting the hydrogen which passed through the pores and was able to ignite it. It is said that a French investigator has succeeded in generating 40 atmospheres of pressure inside such a vessel under almost similar conditions. Another investigator, Mr. Stanley Meikle, has passed hydrogen through a steel diaphragm from one vessel to another. In Mr. Meikle's experiments he closed one end of a glass tube with a steel plate of approximately 30 mm. thickness. Inside of the vessel so formed he placed a neutral solution. The vessel was then immersed in a solution of hydrochloric acid for some time and upon testing the neutral solution it was found that it gave an acid reaction. There is, therefore, no lack of evidence that hydrogen will readily pass through a comparatively thick wall of steel or iron.

Perhaps no better illustration of the affinity of hydrogen for iron could be presented than the result of giving a spring a coating of japan. In certain japanning processes the iron or steel article is made the anode, the japanning being done electrolytically, which means that the hydrogen is being driven in the opposite direction and away from the iron; still the metal shows the same defect as is shown by all pieces of steel which have absorbed hydrogen, *viz.*, the piece becomes brittle, losing its properties of malleability and ductility.

The discrepancy of theory shown above is hard to explain. It must be that at the moment the hydrogen is generated at the anode and before it can escape into the stream of moving ions, it is absorbed by the iron, and this in spite of the electromotive force acting against it.

In the ordinary enameling process the metal parts are first "scaled," as the process of burning off the grease and forming a coating of iron oxide is called. The iron oxide is then removed by placing the parts in a warm bath of hydrochloric or sulphuric acid. The usual strength of this solution is in the neighborhood of 10 per cent acid, fresh acid being added from day to day to replenish the amount exhausted in combining with the iron and iron oxide.

In the manufacture of sheet steel for enameling, the steel is rolled to the desired thickness by passing the sheet between heavy rolls which are spaced at various distances from each other according to the thickness of sheet desired. In forming the ingot from which the sheet is rolled, air bubbles are incorporated unless the workmen are particularly careful in the pouring. In the rolling-out process these blebs are made much thinner in section but their size in a lateral direction is enormously increased so that an air bubble, which in the ingot was about the size of a pin head, would appear in the rolled sheet as a space of infinite thinness, but perhaps of one or two square inches in area.

Noting these facts in connection with the manufacture of enameling-steel and also keeping in mind what has been said before with respect to the action of hydrogen upon steel, it is very easy for one to theoretically, at least, see whereby hydrogen from the pickling process might enter the iron sheets, the hydrogen ions congregating in the small interstices caused by the rolled-out air bubble and upon heating expand, causing a separation of the iron at this point as evidenced by the disagreeable blistering.

Experimental.

In order to investigate the probability of such an occurrence and in order to find out if this were really the true cause of this sort of blistering, the following experimental work was carried out on a commercial scale in our enameling plant:

Lot. No. 1.—Ten reflectors were picked at random from a batch of stampings, sand-blasted and enameled in the usual way.

Lot No. 2.—Ten pieces were taken from the same lot, scaled, pickled and enameled in the usual way.

Lot No. 3.—Ten pieces were dipped in a 10-per cent HCl solution and scaled in the usual way.

Lot No. 4.—Ten pieces were scaled, pickled in a 3-per cent HCl solution and enameled in the usual way.

Lot No. 5.—Ten pieces were scaled, pickled in 10-per cent. H_2SO_4 solution and enameled in the usual way.

Lot No. 6.—Ten pieces were dipped in 10-per cent H_2SO_4 solution and scaled.

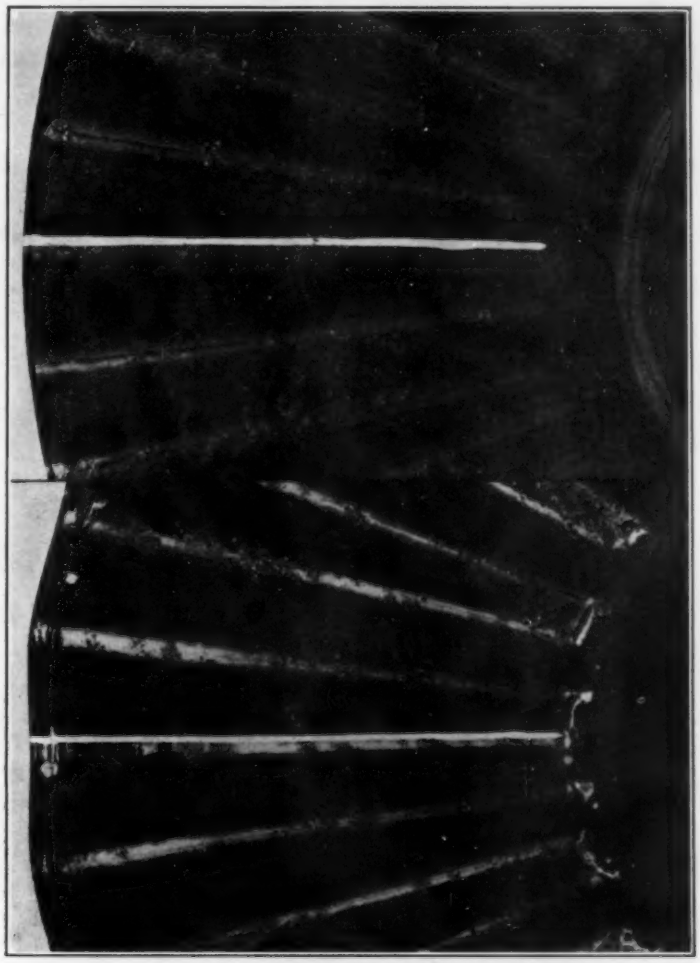


FIG. 1.—Enameled reflectors showing blow-hole defects which blistered when enameled.

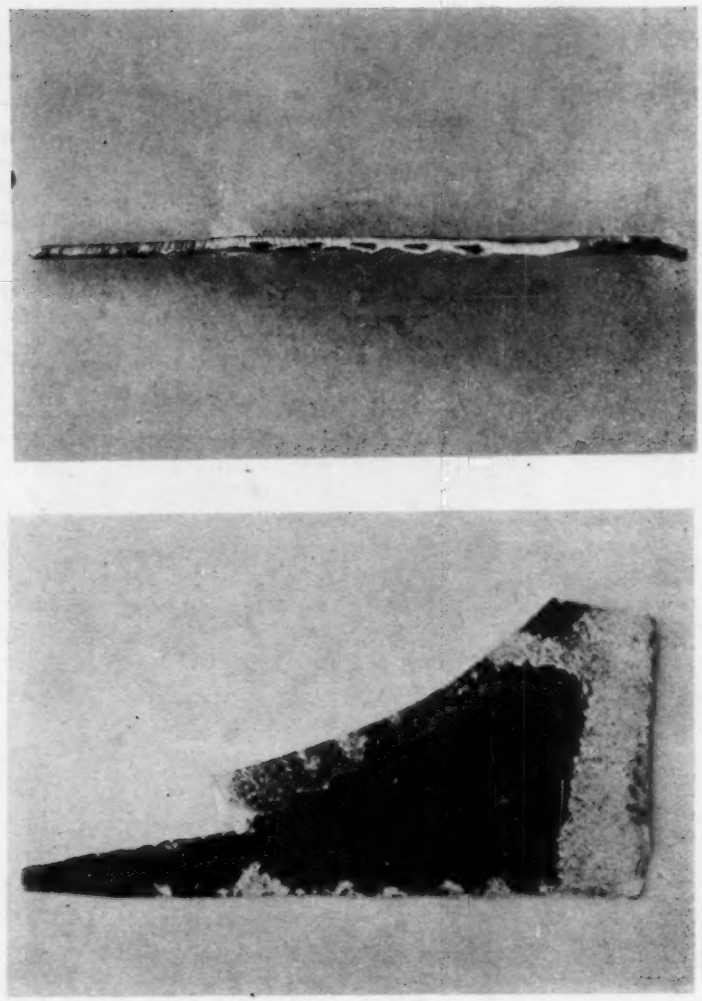


FIG. 2.—Sections enameled reflectors showing blow-hole defects which blistered when enameled.

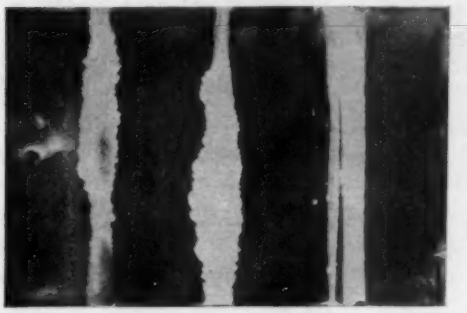


FIG. 3.—Pickled in acid.

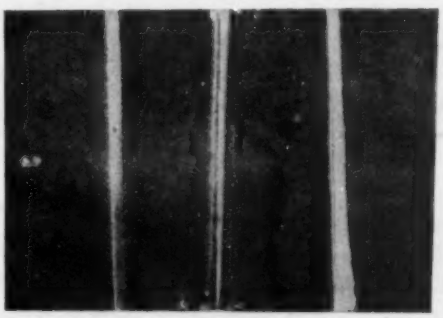


FIG. 4.—Vacuum treated.

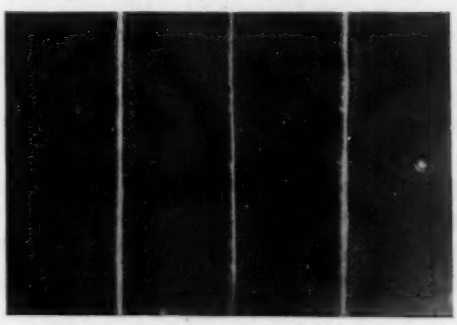


FIG. 5.—Sand blasted.

Lot No. 7.—Ten pieces were scaled, pickled in 3-per cent H_2SO_4 and enameled in the usual way.

Results.

The results of these experiments were as follows:

Lot No. 1.—None of these reflectors showed any signs of blistering.

Lot No. 2.—Every reflector in this lot showed marked blistering, the blisters varying in size from $^1/_2$" diameter to blisters having an area of 2 or 3 sq. in.

Lot No. 3.—All of these reflectors showed blisters when taken from the furnace after scaling.

Lot No. 4.—None of these reflectors showed blisters.

Lot No. 5.—All the reflectors in this lot showed blisters similar in size and character to those shown in Lot No. 2.

Lot No. 6.—All of these reflectors showed blisters similar in size and character to those of Lot No. 3.

Lot No. 7.—None of these reflectors showed blistering.

Conclusions.

From the results of the above experiments it can be readily seen that the hydrogen certainly has much to do with the blistering in sheet-steel enameling. Those reflectors which were pickled in a strong solution of acid all showed blistering. This is no doubt due to the high concentration of liberated hydrogen ions which must necessarily take place when the iron is placed in an acid solution of such a strength. The reflectors which were pickled in a solution weak in acid necessarily were not acted upon as rapidly by the acid as in the case of the strong acid concentration. The concentration of liberated ions could not pile up so rapidly and therefore there was less penetration of the ions into the steel sheets. In the case of the lots which were dipped in acid before scaling, we have the evolution of hydrogen in the acid bath, together with the accompanying absorption of the hydrogen ions. These ions, lodging in the minute cavities caused by the rolled-out blow holes in the steel sheet, expand upon heating, causing the separation of the sheet accompanied by a noticeable blister at this point.

In order to make commercial use of the results of these experiments, it would be necessary to change the strength of the pickling solution to about 3 per cent. The time of pickling would not be very noticeably increased, although it would be necessary to have a workman rub each piece with a brush before washing—to help remove some of the adhering scale. In our case the quality of ware produced by such a change has resulted in practically no cases of blistering over a period of ten months, whereas with the use of the old method losses of 40 per cent were not uncommon on some lots of stampings.

GENERAL ELECTRIC CO.,
SCHENECTADY, N. Y.

A METHOD FOR DETERMINATION OF THE VOLATILE MATTER IN OXIDES OF LEAD.

By Olaf Andersen.

For calculation of glass batch compositions it is necessary to know exactly the amount of PbO in the litharge or red lead used. If special tests show that the material contains no appreciable amount of metallic impurities, the obvious method is to drive off all volatile matter (CO_2, H_2O, and O present in PbO_2) by ignition. The residue may then be figured as pure PbO. In trying to do this, however, one will meet a difficulty at the very outset. The volatile constituents are driven off only slowly and to insure their expulsion in a reasonable period of time the oxide should be carried to its melting point. If, however, the sample is heated until melting takes place the containing crucible will be badly attacked. In order to overcome this difficulty the modification of the ignition method described below was worked out.

The ignition is done in a platinum crucible of almost any size or shape, but preferably of small diameter which will give the melt a relatively small surface and thereby diminish the loss by volatilization of lead oxide. To prevent any attack of the platinum the lead oxide sample is mixed with silica (sand or ground quartz) in the proportion of about 3 weights of PbO to 1 weight of SiO_2. On account of the formation of a low melting compound and eutectics in such a mixture the melting will take place at a temperature nearly 100° C, below the melting point of pure PbO (about 880°), and the result will be a silicate melt which does not appreciably attack the platinum.

The procedure for the determination is as follows: The sample is weighed in a platinum crucible. An amount of silica[1] equal to about one-third[2] of the assumed amount of PbO in the

[1] The silica used here must not merely be dried at 100° or 200° but, previous to use in this method, it should be ignited to 1000° to completely remove volatile matter. This procedure is advisable in all cases and absolutely necessary with silica derived from carbonate-carrying sands.

[2] At the Charleroi plant we used 4 of lead oxide to 1 of silica.

sample is added to the latter and the two are carefully mixed in the crucible; finally, a thin layer of silica is spread over the top of the mixture. The crucible with full charge is weighed and placed inside an electric furnace previously heated to 800°. The temperature must be accurately measured and must not be permitted to change considerably. The heating at 800° is continued for about 20 minutes and the temperature is raised as quickly as possible to about 1000° where it is held for about 15 minutes more. Then the crucible is taken out, covered to prevent the cracking glass from flying out of the crucible, cooled and weighed. The loss in weight is the amount of volatile constituents present in the lead oxide and, in case there are no other impurities, the remainder of the original sample is pure lead oxide, PbO.

The method has been used to a considerable extent in connection with our optical glass work at the laboratories of the Pittsburgh Plate Glass Company at Charleroi, Pennsylvania, and the Spencer Lens Company at Hamburg, New York. The results checked well with a few direct analyses made on some of the samples. The average run of the figures obtained on litharge is indicated by the following examples:[1]

Average of 14 samples litharge	98.99 per cent PbO
Maximum of 14 samples litharge	99.55 per cent PbO
Minimum of 14 samples litharge	98.00 per cent PbO
Top layer of barrel which had stood open 4–6 weeks	97.27 per cent PbO
Top layer of barrel which had stood open 4–6 weeks	96.61 per cent PbO

GEOPHYSICAL LABORATORY,
CARNEGIE INSTITUTION OF WASHINGTON,
August, 1919.

[1] Data furnished by R. H. Lombard.

THE VOLATILIZATION OF LEAD OXIDE FROM LEAD SILICATE MELTS.

By Olaf Andersen.

The experiments described below were undertaken in the course of the Geophysical Laboratory's work on optical glass during the war, in order to determine the order of magnitude of the loss due to volatilization of lead oxide from lead silicate melts under certain conditions. An exact determination of such data, with perfect control of all determining factors, would involve a very comprehensive set of experiments, but approximate results may be obtained with simple means.

The material for the experiments consisted of homogeneous glasses containing, apart from incidental impurities, only lead oxide and silica in various proportions. The heatings were done in the same electric furnace in which the experimental glasses had been made, with the opening covered but not tightly closed. The broken glass was filled into a platinum crucible, which had been previously tested for approximate constancy of weight under the conditions of the subsequent experiment. The crucible with charge was heated until the glass formed a melt with level surface, then cooled and weighed. The furnace was then regulated to the temperature desired for the experiment and the crucible was introduced and held for a certain time, taken out, cooled, and weighed again. The difference between the two weighings gives the loss in the melt and as the only volatile constituent in every case was lead oxide, the total loss may be safely calculated as PbO. The area of the surface was then measured.

A few tests showed that the actual loss from the same melt at the same temperature was proportional to the area of the exposed surface and independent of the weight of the melt. The factor determined was therefore the rate of loss per unit of the exposed surface of the melt. The units used were 1 hour, 1 square centimeter, and 1 milligram.

It was found that the rate of loss decreased with a prolonged heating when the melt was left without stirring, but remained constant when stirring was applied. The explanation of this is that diffusion alone works very slowly and will only partly offset the change in composition due to volatilization of lead oxide from a thin film next to the surface of the melt. This film will therefore become gradually richer in silica, at the same time growing lighter than the underlying melt so that it will remain at the top as a protecting film and thereby diminish the rate of volatilization. If, on the other hand, the melt is stirred the rate of volatilization will remain practically constant for a long time because the total loss of lead oxide will be distributed throughout the melt and the actual change in composition of the whole melt, and consequently also of the surface film, will be small. To obtain the exact rate of loss for a certain melt it should therefore be necessary to stir it during the entire period of heating.

This, however, would involve a rather complicated arrangement of experiments and would consume much time. Tests were therefore made to find out whether the rate of loss computed from a short heating without stirring would not be materially the same as the one obtained through a prolonged heating with stirring. The experiments in Table 1 were carried out with a melt of the composition: 70 per cent (by weight) PbO, 30 per cent SiO_2, at a temperature of 1300°.

TABLE 1.

Volatilization of PbO under Different Conditions.

Time of heating.	Condition.	Rate of loss mg./hr./sq. cm.
20 hours	No stirring	8
15 min.	No stirring	23
1 hour	With stirring	22

These tests show that the rate obtained on the basis of a short heating without stirring is practically identical with the one obtained by a somewhat longer heating with continual stirring.

It is also seen that a prolonged heating without stirring gives a much lower rate of loss than either of the other methods.

In view of these facts the computed rates of loss were based on a short heating without stirring of the melt. A period of 15 minutes was found convenient.

The results are tabulated in Table 2 and plotted in Fig. 1.

TABLE 2.

Volatilization of PbO from Pure Lead Silicate Glasses.
(Loss in mg./hr./sq. cm.)

Percentage of PbO in glass.....	85	78.7	75	70	65	60
Temperature °C.						
1400	318	131	91	60	46	33
1300	100	40	30	23	16	13
1200	37	11	8	7	5	4
1100	13	4	2	2	1	1
1000	8	2	1	1	..	..
900	1	1	..	..	..	..

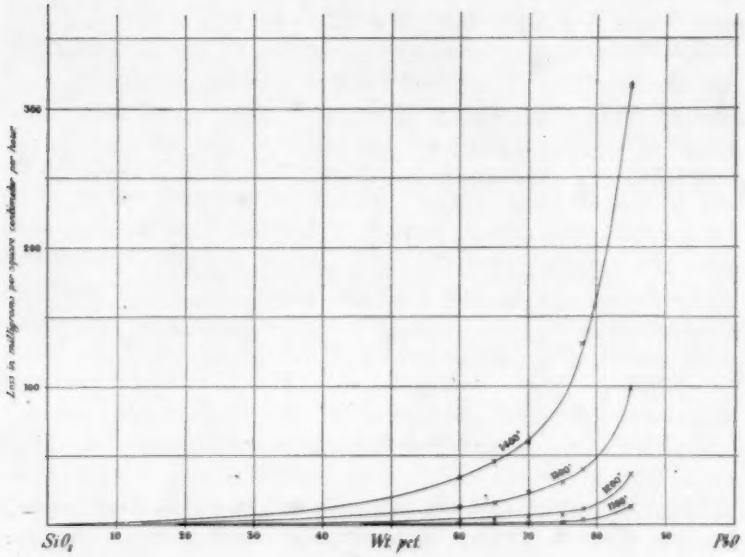


Fig. 1.

In several cases the refractive indices at various depths of the melt were determined after certain heatings. It was invariably found that a thin layer near the surface, and sometimes a film creeping up along the inside of the crucible, showed a considerably lower refractive index than the underlying glass. Table 3 contains a few examples of this relation.

TABLE 3.

Volatilization of PbO from Surface of Glass Melt.

Time of heating.	Composition.		Refractive index after heating.		Remarks.
	SiO_2.	PbO.	Middle of glass.	Surface film.	
2 hours	21.3	78.7	1.888	1.860	
3 hours	11.9	88.1	2.09	1.63	Surface film creeping
2 hours	35.0	65.0	1.724	1.70	up inside of crucible

During the experiments it was often noticed that small isolated patches of thin glass film on the sides of the crucible very soon lost so much lead oxide that silica began to crystallize out, the glass becoming white. Under the microscope the crystals were found to be tridymite, which, according to Fenner,[1] is the stable form of silica between 870° and 1470°.

To apply the results to actual glass-melting one may take the following example: A glass containing 60 PbO and 40 SiO_2 is heated for 48 hours at 1300°. Suppose the area of the surface to be 7500 sq. cm. (approximately the area exposed in a pot of 39 inches inside diameter). The loss according to the diagram (Fig. 1) is 48 × 7500 × 13 mg. or 4.68 kg. On a 1000 kg. charge this means a loss of about 0.5 per cent of the weight of the glass, or 0.8 per cent of the PbO. This will have an influence on the refractive index of about 2 in the third decimal place. Similarly, if this glass were fined at 1400°—the usual practice—the loss[2] by

[1] C. N. Fenner, *Am. J. Sci.*, **36**, 331–384 (1913); *J. Soc. Glass Tech.*, **3**, 116–125 (1919).

[2] With the shortened melting and fining schedules used more recently the losses would be approximately half those calculated.

volatility would be 12.2 kg. PbO which is equivalent to 1.22 per cent on the weight of the glass or 2.0 per cent on the weight of PbO. Since melts of a particular kind of glass are always given as nearly as possible the same kind of treatment, the loss will be subject to only small changes from melt to melt and any considerable variation in refractive index is probably not to be ascribed to a variation in the amount of lead oxide lost through volatilization from the surface of the melt. If, however, the heating schedule of the same melt has been considerably changed a noticeable variation in optical properties due to change in loss by volatilization must be expected in all melts rich in lead oxide. This factor is probably largely responsible for the considerable variations in optical properties found in melts, presumably of the same composition, made experimentally on a small scale to determine the relation of optical properties to composition in the lead glasses.[1]

That volatilization is a factor of large magnitude is apparent to anyone who has observed the dense "smoke" issuing from the opening of a covered pot containing a lead glass melt which, on account of accident, has been taken from the furnace at the fining temperature. The vapors in this case consist not only of lead oxide but also of alkalies and boric oxide; the opacity and apparent magnitude of the cloud is increased by the condensation of these vapors to solid particles on striking the cold air, but even after allowing for this impression the amount of material evolved is surprisingly large.

The losses of PbO observed in large-scale operations have at times actually reached figures in excess of 5 per cent of the PbO content. These large losses were partly caused by volatilization as above described, but also, in addition, by litharge being mechanically carried out of the pot by gases such as O, CO_2, and oxides of nitrogen derived from the decomposition of batch materials. Such losses were particularly noticeable with the extremely finely-divided sublimed litharge used so extensively in the last year of the war. The rate of filling in the batch would be an important factor in determining such losses, and likewise

[1] Data to be presented in a subsequent paper.

also the practice in regard to stoppering the opening of covered pots, when such pots were used.

Summary.

Experiments were made on the amount of PbO volatilized from the surface of lead silicate glasses at temperatures from 900° to 1400° C. It was found that the volatilization from an unstirred glass in 15 minutes took place at practically the same rate as from a stirred glass heated for a longer period. The rate of volatilization falls off considerably during a long heating if the glass is not stirred, as a film considerably lower in PbO forms on the surface of the melt, into which PbO must diffuse from below before it can escape. The rate of volatilization of PbO at temperatures usually used in optical glass manufacture would seem from these experiments to be small enough so that variations in refractive index due to volatilization are not to be expected if the procedure is reasonably constant from melt to melt, but large enough to cause considerable variations in index if the melting schedule is changed.

GEOPHYSICAL LABORATORY,
CARNEGIE INSTITUTION OF WASHINGTON,
August, 1919.

DISCUSSION OF AN ARTICLE BY ELLIS LOVEJOY, ENTITLED, "NOTES ON FIRE CLAYS OF THE NORTHERN APPALACHIAN COAL BASIN," IN THE MAY NUMBER OF THE JOURNAL OF THE AMERICAN CERAMIC SOCIETY.[1]

By George H. Ashley.[2]

First. The stratigraphic position of the flint clays as described by Mr. Lovejoy has been questioned, but I think that Mr. Lovejoy is correct in assigning the principal deposits in the northern Appalachians to the horizons of the Sciotoville, Upper Mercer, Lower Kittanning, and Upper Freeport. These are by no means all of the horizons but flint clay is widespread at at least the last three of those horizons. At Bolivar, Pa., and some other places, the flint clay is below the Upper Freeport limestone and in a measure distinct from the under-clay of the Upper Freeport coal, but at hundreds of other places the flint clay is so close below the coal that for all practical purposes the horizon may be spoken of as at the horizon of the Upper Freeport clay. Flint clay has been found at a few localities under what has been correlated as the Upper Kittanning coal. I do not recall a single instance of its occurrence under the Middle Kittanning coal though it may so occur. Its occurrence under the Lower Kittanning coal, that is, between that coal and the Vanport limestone, is so common as to form one of the "earmarks" of that coal. In this position it is frequently referred to as the Clarion flint clay, as it occurs at this horizon in the town of Clarion and at scores of places in every direction from the town. There seems to be little doubt that the upper clay, all through the Woodland district of Clearfield County, Pa., is under the Lower Kittanning coal or else the Allegheny stratigraphy of central Pennsylvania must be recast. It is found at the same horizon from central Pennsylvania as far southwest as northeastern Kentucky. In

[1] *J. Am. Ceram. Soc.*, **2**, 374 (1919).

[2] By permission of the Director, U. S. Geological Survey.

scores of places its position between the Vanport limestone and the Lower Kittanning coal is so clear as to leave no doubt as to its horizon. Recent intensive work in the Mount Savage area of Maryland, by Messrs. Harvey Bassler and Charles K. Swartz of the Maryland State Survey, extended by studies into the type areas of Pennsylvania (Kittanning, Brookville, Mercer, and others), and recent work by the Federal Survey in Somerset County, and stratigraphic studies in the Beaver River and Allegheny valleys, have indicated the possibility that some of the so-called Mercer flint clays may belong at the base of the Allegheny or in the horizon of the Clarion and Brookville coals. At the town of Clearfield, Pa., and at a few other places, there is a remarkable succession of flint clays extending from just below the Lower Kittanning coal downward for 60 feet or more, interbedded with a number of thin coals.

Second. I am inclined to believe with Mr. Lovejoy that flint clay may be the result of secondary chemical changes, yet the persistent recurrence at a few definite horizons argues for there having been original differences in the deposits in which they occur from the other argillaceous deposits of the region. Thus, it is a common experience, particularly with the clay at the Lower Kittanning horizon, to find the flint clay confined to the front of the hill, where it is under light cover, and that as the bed is followed under the hill the flint clay disappears. This suggests secondary action by surface waters. Again, the extreme irregularity of the bodies of flint clays in the general mass of soft clay, as figured by me in the report of the Topographic and Geologic Survey Commission of Pennsylvania, 1906–8, page 316, suggests secondary action. On the other hand, where the bed of flint clay can be traced almost continuously for many miles it would appear to be a primary deposit, or at least based on differences in the original argillaceous deposit, in contrast with other adjacent argillaceous deposits. For example, there are in Kentucky two horizons of this kind. In northeastern Kentucky there is quite an area where the thick clay under the Lower Kittanning coal has in the middle a layer of flint clay only a few inches thick. Again, in southeastern Kentucky there is a coal bed known as the Fire Clay coal, the Hayden, or No. 4 bed, which at hundreds

of openings shows a parting of flint clay. This has been traced over a large area through Letcher, Leslie, Harlan, Clay, Knox, Bell, and Whitley counties, Kentucky, and into Claiborne, Campbell, Anderson, and Scott counties, Tennessee, forming the best key horizon in the whole region. Again, in north Beaver County and south Lawrence County, Pennsylvania, and apparently at the same horizon elsewhere in Pennsylvania, there is a deposit of flint clay entirely unassociated with either soft clay or coal. It occurs in the shale of the Mahoning interval above the Upper Freeport coal. It is not commonly a distinctly marked horizon but a narrow belt in which the shale gradually changes over into a flinty shale and locally into a ferruginous flint clay, and at the top changes back into the overlying shale. The shale where affected breaks down like crushed flint, crunching under buggy wheels like broken glass. This belt in the area mentioned is so regular as to serve as a key horizon in mapping. These occurrences at widespread horizons seem to indicate that flint clays if of secondary origin originate only in deposits having characteristic original differences from other shaly or clayey deposits. What those differences were or how they may have originated, I can not say.

Third. Mr. Lovejoy's distinctions of the flint clays at the four principal horizons agrees in general with my observations though I have not found it safe to put much weight on those apparent differences for stratigraphic purposes.

Fourth. In so far as Mr. Lovejoy has put weight on Stout's theory of origin of clays associated with coal, I fear he is on the wrong track. This is not the place to discuss that theory, but I believe the examination of several thousand under-clay sections will convince any one that the under-clays are not uniform vertically, as demanded by the theory, but are generally, if not universally, different at the top and bottom, the bottom usually being more sandy if the underlying bed is a sandstone, and in many, if not most places, grading into the underlying bed, whatever that may be. Nor can any one trace clay partings in coal beds from mine to mine, particularly in horizons where the benches spread apart and reunite irregularly, and watch closely the change in the character of the partings from point to point

without becoming convinced that he is dealing with an ordinary widespread sedimentary deposit. Some of these partings are remarkably persistent and uniform over large areas, but is not the very delicate adjustment of physical conditions necessitated by Stout's theory much more difficult of imagination than the common one of a widespread flooding by mud-carrying waters? Certainly the shoreward edges of such partings, which generally tend to thicken and become sandy, indicate water deposits. The theory would have difficulty in accounting for sandstone partings, which in some areas have a wide enough extent to serve as keys in the correlation of the beds. That underclays *may* have been affected by the action of plant growth going on over them is clearly evidenced by the apparent effect of such growth on sandstones, which in many places underlie the coals in place of clays. Such sandstones, especially where penetrated by Stigmaria, are commonly whitened next to the coal, locally to depths of 4 to 5 feet or more, and this white sandstone is found to be freer of alkalies than the adjoining sandstones, and is locally called ganister and so used in the lining of furnaces.

TOPOGRAPHIC AND GEOLOGIC SURVEY OF PENNSYLVANIA,
HARRISBURG, PA.

GLASS-SAND RESOURCES OF VIRGINIA.

By Thomas L. Watson.

Introduction.

The resources of Virginia in quartz sand or its hard rock equivalents suitable for glass-making are very great. Quartz in the form of sand or hard rock desirable for purposes of glass manufacture occurs in each of the three major physiographic divisions of the State, and is produced at present in each province for such use. In many localities the sandstones and quartzites are of exceptional purity. Many of them are favorably located for quarrying and to lines of transportation, and are near to abundant supplies of high-grade coal.

There are four plants in Virginia engaged at present in the manufacture of glass, located at Alexandria, Richmond, Lynchburg, and Salem, with a fifth one expected to begin operating shortly at Norfolk. Of the four producing plants two derive their supply of sand from Virginia while the others obtain their supply from West Virginia. The total production of glass-sand, which is not very large, is consumed within the State.

Kinds of Material.

The kinds of silica found in Virginia in quantity and of sufficient purity (see table of analyses on page 797) to be utilized in making glass include (1) quartz sand, (2) sandstone and quartzite, and (3) vein quartz including some pegmatite occurrences. These materials probably have not equal value for glass-making and, under present conditions, some of them may not be usable, although well located and occurring in quantity and of sufficient purity. The distribution and character, including analyses of these materials, are briefly summarized below by physiographic provinces.

Coastal Plain Province.

The Coastal Plain or Tidewater Virginia, the easternmost province, comprises about one-fourth the total area of the State.

The major streams which cross it are navigable for the entire width of the province and with the lines of railway afford excellent transportation facilities.

The Coastal Plain province is composed of loose or locally indurated sediments, of which sands of different kinds form an important part. The sands vary greatly both as to size of grain and purity. In many localities they consist of pure quartz grains but more often they are admixed with more or less clay and iron oxide, and may carry small grains of other minerals than quartz, such as magnetite, ilmenite, etc., but not in harmful amounts in some of the deposits. Glauconite, an iron-bearing mineral, is usually an abundant constituent in many of the Eocene sands which are of little or no value for glass manufacture when this mineral occurs in appreciable quantity.

The better grades of the Coastal Plain sands have been employed in a variety of uses but in greatest quantity for building purposes. Some of the sands are pure enough to be utilized for glass-making, but thus far they have been so employed only to a very limited extent.

Extending from Cape Henry southward into North Carolina, sands dune are prominently developed along the coast, forming a conspicuous feature of the coastal topography. The material is loose beach-sand accumulated landward by the wind. Small shipments of this sand in the vicinity of Cape Henry are made at present to one of the Virginia plants for glass-making. Because of their extent and favorable location (only a few miles east from the city of Norfolk), these sands are worthy of careful investigation in order to determine their desirability for glass manufacture.

Extending along the western margin of the Coastal Plain, from Fredericksburg northeastward to the Virginia boundary, is a belt of Cretaceous sands sufficiently indurated locally as to have been formerly quarried for building stone. They are essentially light-colored sands, composed in places almost entirely of pure variable-size quartz grains, but they frequently contain much kaolinized feldspar. It seems probable that, in certain localities within this belt, the sands might be utilized to advantage in the manufacture

of at least the lower grades of glass. So far as we are aware, however, no attempt has yet been made to use them.

Piedmont Plateau Province.

As defined at present, the Piedmont Plateau province comprises that part of Virginia included within the fall belt on the east and the southeast slope of the Blue Ridge Mountains on the west. It is composed dominantly of a complex of the older crystalline silicious rocks, although several areas of Triassic rocks are comprised within its limits. Belts of metamorphosed sediments yielding crystalline limestones, quartzites, and slates of early Paleozoic age also occur.

Within the Piedmont province are distributed several kinds of highly quartzose materials, including quartzite, quartz veins, and pegmatite bodies, some of which are sufficiently pure and otherwise desirable for glass manufacture.

The stream sands deposited along river courses in the Piedmont province are usually too impure to be seriously considered for purposes of glass manufacture. Most of the quartzites are likewise too impure to be used in glass-making, since they may carry large but varying amounts of either micaceous minerals, feldspar, epidote, or iron oxides (chiefly magnetite and ilmenite, and in places hematite). In some localities, however, the quartzites are entirely white in color; are composed almost wholly of pure quartz, with inappreciable amounts of other minerals; and could be used to advantage in glass-making.

Only one locality in the Piedmont Plateau is yielding quartzite or its disintegration product, quartz sand, at present for the manufacture of glass. A white quartzite of Lower Cambrian age, located near Stapleton in Amherst County, about 12 miles north of east from the city of Lynchburg, is being utilized by the Lynchburg plant for the making of glass. A partial analysis of a sample of this quartzite is given in the table of analyses on page 797. The sample yielding the analysis, however, contains, besides quartz, considerable white, silvery mica (sericite). Other analyses of samples of the quartzite indicate more than 95 per cent of silica, with only a trace of iron. Fusion tests made on a sample of the rock yielded a very satisfactory grade of glass. Similar quartzites

TABLE 1.—ANALYSES OF VIRGINIA GLASS SANDS.[1]

Piedmont Plateau Province.

	1.	2.	3.	4.	5.
SiO_2	91.403	94.37	99.870	99.638	99.33
Fe_2O_3	0.476	0.07	0.930	0.025	....
CaO	0.260	....	....	....	....
Ignition	1.780	0.93	0.068	0.184	....
Undetermined	6.081	4.63	....	....	0.67
	100.000	100.00	100.868	99.847	100.00

Mountain Province.

	6.	7.	8.	9.	10.	11.
SiO_2	99.66	99.08	99.471	98.78	96.99	98.546
Al_2O_3	0.18	0.18	....	0.27	0.01	....
Fe_2O_3	0.09	0.32	0.076	0.41	0.02	0.099
MgO	....	...	....	...	0.07	....
CaO	....	...	0.030	...	0.80	....
Na_2O, K_2O	0.07	0.40	....	...	1.60	....
TiO_2	....	...	....	...	...	0.060
Ignition	....	...	0.129	...	0.31	0.327
	100.00	99.98	99.706	99.46	99.80	99.032

[1] Nos. 1 and 2. Cambrian quartzite near Stapleton, Amherst County, Virginia (S. D. Gooch, analyst).

No. 3. Silex (vein quartz), Madison Courthouse, Madison County, Virginia (S. D. Gooch, analyst).

No. 4. Silex (vein quartz), 1 mile east of Boyd Tavern, Fluvanna County, Virginia (S. D. Gooch, analyst).

No. 5. Silex (vein quartz), near Scottsville, Albemarle County, Virginia (J. B. Weems, analyst).

Nos. 6 and 7. Cambrian (Erwin) sandstone from Locher place (Glasgow Clay Products Company), near Glasgow, Rockbridge County, Virginia.

No. 8. Silurian (Clinch) sandstone near Kermit, Scott County, Virginia (S. D. Gooch, analyst).

No. 9. Silurian (Massanutten-Tuscarora) sandstone, Catawba Mountain, 9 miles north of Salem, Virginia. (By courtesy of the Salem Glass Company, Inc., Salem, Virginia.)

No. 10. Catawba Valley sand (Massanutten-Tuscarora sandstone), 9 miles north of Salem, Virginia (H. H. Hill, analyst).

No. 11. Cambrian (Erwin) sandstone, C. & O. railroad quarry, east of Basic, Augusta County, Virginia (S. D. Gooch, analyst).

of equal purity and of the same geologic age are found in other localities in the Piedmont province, but have not yet been drawn on as a source of raw material for glass manufacture.

Large bodies of exceptionally pure quartz are widely distributed over many parts of the Piedmont province which, judging from the analyses given on page 797, could be utilized in many cases to advantage in glass-making. The quartz of the numerous pegmatite bodies occurring in the Piedmont province is probably of less importance because of the size of the pegmatites and the irregular distribution of the quartz in them, in this connection than either the quartzites or the vein quartz, although the quartz can be readily separated from the feldspar, both of which are used in the manufacture of pottery.

Mountain Province.

This province embraces the western part of the State; its eastern boundary is the southeast slope of the Blue Ridge and its western limits mark the boundary between Virginia, West Virginia, and Kentucky. It includes the following topographic divisions: (1) The Appalachian Mountains to which the name Blue Ridge is applied in Virginia; (2) the Appalachian Valley which is divided lengthwise into an eastern part known as the Great Valley and a western part referred to as the Valley Ridges; and (3) the Appalachian Plateau, the Virginia portion of which includes the extreme southwestern part of the State adjacent to Kentucky and West Virginia. The Appalachian Mountains and Appalachian Valley provinces extend in a general southwest direction over 300 miles from the northern to the southern boundary of the State.

Of the subdivisions of the Mountain province the Appalachian Valley, which is composed of folded Paleozoic sedimentary rocks ranging from Cambrian to Carboniferous (Mississippian) in age, contains vast glass-sand resources in the form of sandstones and quartzites. Notwithstanding this fact there is only one glass-making plant operating at present in this part of the State.

The formations of the Appalachian Valley that either contain abundant supplies of silica suitable for glass-making or are worthy

of careful investigation for such use may be tabulated in the order of their age, beginning with the oldest, as follows:

Cambrian:

1. Unicoi sandstone which includes the Weverton sandstone and Loudoun formation in northern Virginia and adjacent parts of West Virginia.

2. Erwin quartzite which includes the Antietam sandstone of northern Virginia and adjacent parts of West Virginia and western Maryland.

Silurian:

3. Clinch sandstone which includes the Tuscarora (Massanutten) sandstone of west-central and northern Virginia, and adjacent parts of West Virginia.

4. "Rockwood" formation.

Devonian:

5. Oriskany ("Monterey") sandstone.

Mississippian:

6. Pocono sandstone which includes the Price sandstone of southwestern Virginia.

The sandstones of each of these formations have wide general distribution in the Appalachian province, but owing to their greater purity in many localities the sandstones of the Cambrian and Silurian systems must be considered the most important sources of silicious material for glass manufacture. As indicated from the analyses on page 797 and from the descriptions below, these sandstones are remarkably free from impurities in places, especially iron, which is essentially absent.

Cambrian Sandstones.—The principal development of the Cambrian sandstones in Virginia, including the Unicoi (Weverton and Loudoun of northern Virginia), and Erwin quartzite (Antietam of northern Virginia) is along the west foot of the Blue Ridge or at the border of the Appalachian Valley and the Appalachian Mountain (Blue Ridge) provinces. In their normal sequence the Unicoi and Erwin are separated by the Hampton (Harpers) shale, which formation is estimated to be at least 400 feet thick in northern Virginia and 600 to 800 feet in southwestern Virginia.

Because of their greater resistance to weathering the sandstones and quartzites of these formations form low knobs and high ridges of considerable prominence in places in front of the main Blue Ridge. "The Erwin quartzite is one of the most conspicuous formations in the region because it makes such prominent rocky ridges and because of its conspicuous white color."[1] Over much of the region the beds of these two formations, especially those of the Unicoi, are of no value as glass sands, but in many localities the massive white to gray beds of sandstone are of sufficient purity to be of importance as a source of sand for glass-making.

The Unicoi formation which directly overlies the crystalline rocks, includes sandstones, arkoses, conglomerates, and quartzites. "In the northern part of the region these beds range from soft arkose through harder arkosic sandstones to hard, gray sandstone and dark, ferruginous quartzite, and associated beds of slaty, argillaceous sandstone. Some of the basal beds have rounded grains and small pebbles of quartz which are usually clear and transparent, though some have an opaline-blue color. Besides quartz there are grains of feldspar, generally chalky white from weathering, and considerable clay and iron oxide."[2]

The Unicoi formation in northern Virginia is probably not less than 1,750 feet in thickness and is probably thicker in southwestern Virginia. Except in northern Virginia and possibly in some places in southwestern Virginia, the Unicoi sandstones are not generally of glass-making quality. East of the main Blue Ridge in Loudoun County some beds of the Unicoi (Weverton) are very white and pure, being composed almost entirely of quartz grains and apparently could be used to advantage in glass-making.

The Erwin quartzite is a massive white rock, the outcrops of which make prominent ridges throughout the region, and in northern and central-western Virginia, especially, it forms a potential source of unlimited supplies of glass sand. "The western foothills of the Blue Ridge over most of the region are composed of this rock, and it also caps many of the ridges of an inner row where there are several lines of ridges. In the northern part of

[1] Va. Geol. Surv., *Bull.* **17**, 17 (1919).

[2] *Ibid.*, **17**, 13 (1919).

the area the formation is generally composed of three massive cliff-making ledges separated by thinner bedded sandstones. . . . . "The cliff-making ledges consist largely of massive beds of dense, white quartzite, some of which are 15 to 20 feet thick without a visible trace of bedding."[1] Analyses of the Erwin quartzite are given in the table of analyses on page 797.

Over much of the southwest Virginia region, especially in Smyth and Wythe counties, white, hard, massive, vitreous quartzite is least abundant of the beds composing the Erwin, and hence the value of the Erwin sandstone over this part of the State is of less importance as a source of supply of glass sand than in the central-western and northern parts of Virginia.

Silurian Sandstones.—Of the two sandstones of Silurian age the Clinch and the coarse, white sandstone next below the Clinch, or the top member of the "Rockwood" formation (Clinton), the former is much the more important for glass-making.

The Clinch sandstone of southwestern Virginia and its equivalent Tuscarora (Massanutten) sandstone of west-central and northern Virginia, is a massive, coarse, white sandstone or quartzite that forms most of the more prominent valley ridges in southwest Virginia. It ranges up to 300 or 400 feet in thickness and is prominently developed in Clinch Mountain which is the most conspicuous of the Valley Ridges. Under favorable conditions the sandstone weathers in places to a white sand composed almost entirely of pure quartz grains.

The glass plant located at Salem, Virginia is using the equivalent of the Clinch sandstone (Tuscarora) which is derived from Catawba Mountain, about 9 miles from Salem, in the manufacture of glass. The rock is crushed and screened and is then ready for use. An analysis of this rock is given in the table of analyses on page 797.

At or near Kermit, a station on the Carolina, Clinchfield & Ohio railroad, Scott County, is one of the most important localities in the State from which a high-grade glass sand of excellent quality can be obtained for glass-making. Here the Clinch sandstone has good development in beds of exceptional purity. The

[1] Va. Geol. Surv., *Bull.* **17**, 15 (1919).

sandstone is composed almost entirely of moderately rounded, fairly uniform-size grains of quartz of great purity, the total ferric oxide amounting to only 0.014 per cent, as determined by the Pittsburgh Branch of the Bureau of Standards on a sample submitted by the writer. Fusion tests made with a second sample of the sand gave an excellent color, even without the use of a decolorizer. This quality of sand should be of considerable interest to manufacturers of optical glass and of other kinds of fine glass. (See table of analyses on page 797 for an analysis of the Clinch sandstone near Kermit.)

Devonian Sandstone.—The Oriskany ("Monterey") sandstone has wide distribution in western Virginia, chiefly in the Valley Ridges province where owing to the hardness of the rock its outcrops usually form knobs and ridges that are often prominent. The formation, which may range up to several hundred feet in thickness, is composed of a hard, fine- to medium-grained calcareous sandstone of light buff to bluish gray color. The quartz grains are cemented by lime carbonate and under favorable conditions the rock weathers readily to sand and loose fragments. The Oriskany sandstone has not been quarried in Virginia for glass-making, but in some localities in the State where the rock is essentially free from iron and other injurious impurities it seems worthy of investigation for such use. It is well known that this sandstone is quarried and used in Pennsylvania and West Virginia for glass-making and in the latter State it is the most important glass-sand horizon yet developed.

Under this heading are included sandstones, mostly unfossiliferous, which may be of Salina (Silurian) age, and which in one locality at least are of marked purity. In a section measured by Mr. G. W. Stose, along the Chesapeake and Ohio railroad on the east side of James River gap through Rathole Mountain, Eagle Rock, a 55-foot thickness was shown of a pure white, sugary, granular sandstone, of probable Salina age, which crumbles to white sand on weathering. The purity, thickness, and location of this sandstone immediately on the railroad render it especially worthy of careful investigation for probable use in the manufacture of the better grades of glass. Some of the sandstone beds below

this one in the section are also quite pure and of considerable thickness, and will probably prove to be of value for the same purpose. The Tuscarora sandstone of hard, white to gray color beds, and alternating with soft, white sandstone beds, poorly exposed, are shown in the same section. These sandstones (Salina? and Tuscarora) are worthy of careful examination and analysis to determine their desirability for glass-making.

Mississippian Sandstone.—The Pocono sandstone of west-central and northern Virginia and its equivalent, the Price sandstone of southwestern Virginia, is a hard, ridge-making rock that is subject to considerable variation in composition in different localities. It frequently carries thin beds of coal near the top and is apt to be conglomeratic in the lower or basal portion. Because of its iron content and the presence of other impurities, together with non-uniformity of texture as generally shown in most of its outcrops over southwest Virginia, the Price sandstone has no value for glass-making, but in west-central Virginia its equivalent, the Pocono, is developed as a heavy bedded white-to-buff quartzite of apparently sufficient purity as to encourage the belief that in some places at least it might be used.

UNIVERSITY OF VIRGINIA.

RELATION BETWEEN THE COMPOSITION AND THE THERMAL EXPANSIVITY OF PORCELAINS.[1]

By F. H. Riddle.

Considerable work has been done in the study of the thermal coefficients of expansion of porcelain bodies, the bulk of which has been contributed by the membership of this Society.[2]

Most of this work has been carried out with a view of determining the safe range of body composition with reference to the behavior of the glaze. In some cases the bodies were fired to a given temperature, irrespective of the maturing or vitrification point, so that, in fact, the bodies compared differed not only in composition but also in structure.

The present work was carried out in connection with a study of porcelains required for severe duty as regards temperature changes and electrical resistance. It was found necessary, therefore, to determine the thermal expansions of a number of compositions, all of which were fired to maturity.

Previous work has shown that the silica content of a porcelain body is an important factor in determining the magnitude of the coefficient of expansion. For the purpose of throwing additional light upon the relation between composition and thermal expansion, a series of bodies was prepared. In addition, other bodies pertaining to a series of other experiments were included in this study.

The test specimens employed were rods, 2 cm. in diameter and of such length that when fired to maturity they measured 31 cm. They were pressed in the stiff-plastic state in a small hydraulic plunger press, which was found to be very satisfactory for this purpose, inasmuch as the rods were remarkably free from laminations. The construction of the press is shown in Fig. 1. The fired bars were forwarded to the Expansivity

[1] By permission of the Director, Bureau of Standards.

[2] Watts, *Trans. Am. Ceram. Soc.*, **13**, 406 (1911); Purdy and Potts, *Ibid.*, **13**, 430 (1911); Boeck, *Ibid.*, **14**, 470 (1912); Purdy, *Ibid.*, **15**, 499 (1913); Bleininger and Riddle, *J. Am. Ceram. Soc.*, **2**, 564 (1919).

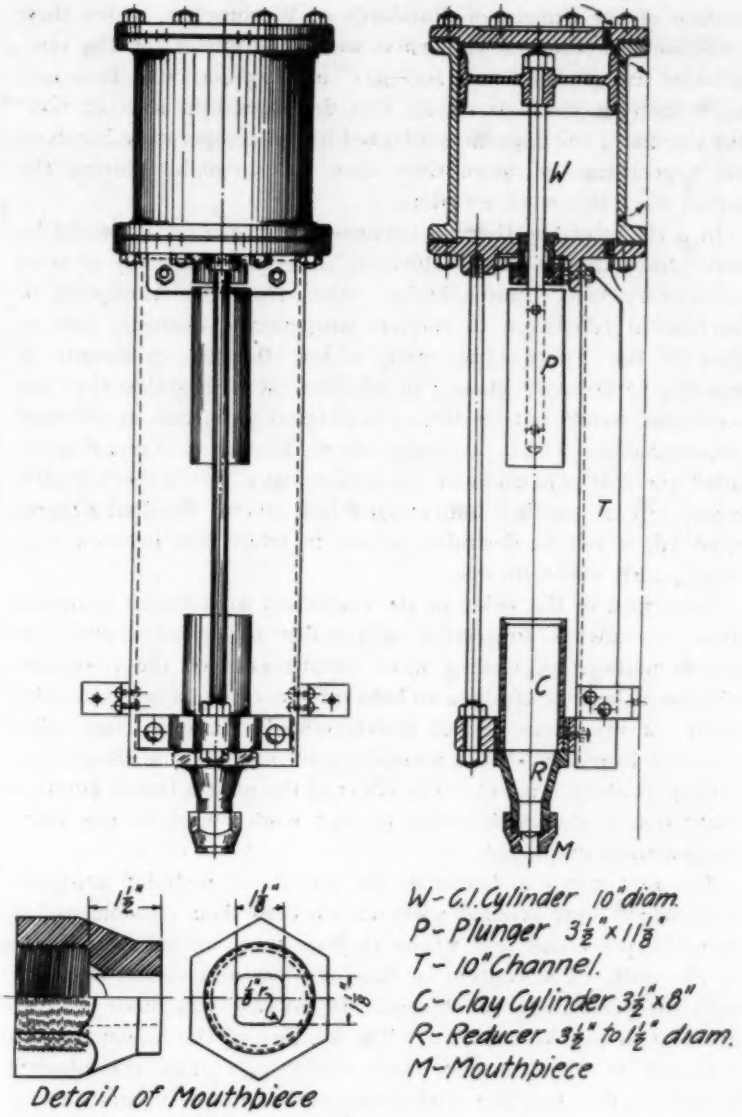

W
P
T
C
R
M
1½"
1⅛"
1⅛"
W-C.I.Cylinder 10"diam.
P-Plunger 3½"x11⅛"
T-10"Channel.
C-Clay Cylinder 3½"x8"
R-Reducer 3½" to 1½" diam.
M-Mouthpiece
Detail of Mouthpiece

FIG. 1.

Section of the Bureau of Standards at Washington, where their coefficients of thermal expansion were determined for the temperature ranges 25–200°, 200–400° and 25–400° C. It would have been desirable to make this determination also at 600° but the use of the apparatus adapted to this temperature involved the expenditure of more time than was available during the period when this work was done.

In a study of the thermal expansion of porcelain it should be understood that a low coefficient, in general, implies a more satisfactory body than a higher value, from the standpoint of mechanical resistance to sudden temperature changes; just as glass of the Pyrex type, with a low thermal expansion, is superior to ordinary glass. In addition, it is desirable that the coefficient should not be subject to decided variations at different temperatures. Thus, a composition having a comparatively small thermal expansion at one temperature, yet a considerably higher one at another temperature but several hundred degrees removed, is not as desirable as one in which the function is a more nearly constant one.

Variations in the value of the coefficient at different temperatures are always suggestive of possible molecular changes or transformations of one or more constituents of the porcelain, whether it be that of alpha to beta quartz, of alpha to beta cristobalite, or inversions as yet undetermined. In case cristobalite has been formed it should manifest itself in a volume change occurring at about 230° C. The effect of the quartz transformation could not be detected in the present work owing to the lower temperatures employed.

The first series of bodies to be considered included compositions which were studied with reference to their possible use as chemical porcelains and whose clay contents varied from 70 to 85 per cent. The content of flint was low and varied inversely with the percentage of feldspar. In no case was more than 50 per cent of raw kaolin used. The balance of the kaolin was introduced in the calcined state (cone 14). The constituents of these bodies together with their coefficients of thermal expansion are given in Table 1. Their chemical compositions are shown in Table 2. The clay content was increased from 70 to 85 per cent

TABLE 1.

Composition of Bodies Used and Their Coefficients of Expansion.

Body No.	51	52	53	54	55	56	57	58	59	60	61	62	63
% Raw kaolin	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
% Calcined kaolin	20.0	20.0	20.0	20.0	20.0	25.0	25.0	25.0	25.0	30.0	30.0	30.0	35.0
% Total clay	70.0	70.0	70.0	70.0	70.0	75.0	75.0	75.0	75.0	80.0	80.0	80.0	85.0
% Flint	18.5	13.5	9.5	5.0	....	13.5	10.0	5.0	....	8.5	5.0	....	....
% Whiting	10.0	15.0	19.0	23.5	28.5	10.0	13.5	18.5	23.5	10.0	13.5	18.5	13.5
% Feldspar	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Coefficient of Expansion $\times 10^{-6}$.													
25–200° C.	6.1	3.4	3.3	3.7	2.3	4.1	3.7	3.2	3.5	4.7	3.3	2.9	3.2
200–400° C.	5.1	3.6	4.4	5.3	3.0	4.1	4.3	3.7	4.5	4.6	3.2	4.0	3.5
25–400° C.	5.5	3.5	3.7	....	3.1	4.1	4.0	3.4	4.0	4.7	3.3	3.5	3.3

TABLE 2.

Chemical Compositions.

SiO_2	64.59	62.90	61.61	60.10	58.52	62.07	60.90	59.27	57.64	59.56	58.36	56.80	55.93
Al_2O_3	30.86	31.76	32.53	33.36	34.25	33.15	33.80	34.70	35.63	35.43	36.08	37.00	38.40
TiO_2	0.15	0.15	0.15	0.15	0.15	0.17	0.17	0.17	0.17	0.18	0.18	0.18	0.19
Fe_2O_3	0.53	0.55	0.57	0.61	0.63	0.56	0.58	0.60	0.64	0.63	0.65	0.62	0.66
CaO	1.07	1.08	1.09	1.10	1.12	1.09	1.11	1.15	1.14	1.10	1.12	1.13	1.13
MgO	0.22	0.23	0.23	0.24	0.25	0.23	0.24	0.25	0.25	0.26	0.27	0.28	0.28
K_2O	1.58	2.08	2.47	2.92	3.40	1.61	1.97	2.45	2.96	1.67	2.05	2.53	2.07
Na_2O	1.05	1.25	1.35	1.52	1.68	1.12	1.23	1.41	1.57	1.17	1.29	1.46	1.34
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Ratio: $\frac{\%\ \text{Silica}}{\%\ \text{Alumina}}$ =	1:2.09	1:1.97	1:1.9	1:1.8	1:1.71	1:1.87	1:1.8	1:1.71	1:1.61	1:1.68	1:1.61	1:1.53	1:1.45

and the flint content decreased from 18.5 to 0 per cent. The silica content therefore decreases gradually from 64.59 to 55.93 per cent. Owing to this comparatively small variation in silica content, there are no marked variations in the coefficients of expansions.

As a whole, it may be said that there is a tendency for bodies high in clay substance to show lower thermal expansions. But it is apparent from the data that bodies high in clay substance have low thermal expansions, fairly independent of the small variations in quartz content which are possible. It is evident that the case is somewhat different with bodies containing 70 per cent or less of clay substance and therefore a silica content of more than 64 per cent. From this point the thermal expansions increased appreciably. This is illustrated by the following two porcelain bodies of normal clay content:

	Body No. 24.	Body No. 220.
Clay	50.0%	50.0%
Flint	34.0	32.5
Feldspar	16.0	16.0
Whiting	0.0	1.5
Coefficient $\times 10^{-6}$ at		
25–200° C.	4.6	6.2
200–400° C.	4.7	4.6
25–400° C.	4.6	5.3

A second series of porcelain bodies was planned to show the effect of replacing flint by synthetic sillimanite ($Al_2O_3.SiO_2$), a material more constant in volume with reference to the thermal expansion. Some of the same bodies given before were included, *i. e.*, Nos. 51, 56, 60, 63 and 220.

The compositions and ultimate chemical analyses of the bodies are given in Table 3. It will be noted that 30 per cent sillimanite was introduced into bodies Nos. 221, 216, 217, 218 and 219. It was substituted for all of the flint and the balance, if any, took the place of calcined clay. In one case, body 221, there was an excess of flint, 2.5 per cent, still remaining after the sillimanite had been added.

The effect of the substitution is shown in Table 4. For convenient reference the contents of clay substance, flint and sillimanite are given together with the coefficients of expansion.

TABLE 3.

Body No.	51	216	56	217	60	218	63	219	220	221
% Raw clay	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
% Calcined clay	20.0	8.5	25.0	8.5	30.0	8.5	35.0	5.0	....	....
% Flint	18.5	....	13.5	....	8.5	....	....	....	32.5	2.5
% Sillimanite	....	30.0	....	30.0	....	30.0	....	30.0	....	30.0
% Feldspar	10.0	10.0	10.0	10.0	10.0	10.0	13.5	13.5	16.0	16.0
% Whiting	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
% Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Chemical Compositions.										
SiO_2	64.59	49.81	62.07	49.81	59.56	49.81	55.93	50.38	72.51	52.10
Al_2O_3	30.86	45.05	33.15	45.05	35.43	45.05	38.40	44.10	22.60	42.24
TiO_2	0.15	0.24	0.17	0.24	0.18	0.24	0.19	0.23	0.16	0.22
Fe_2O_3	0.53	0.64	0.56	0.64	0.63	0.64	0.66	0.63	0.44	0.59
CaO	1.07	1.11	1.09	1.11	1.10	1.11	1.13	1.13	1.05	1.10
MgO	0.22	0.28	0.23	0.28	0.26	0.28	0.28	0.27	0.18	0.26
K_2O	1.58	1.67	1.61	1.67	1.67	1.67	2.07	1.98	1.98	2.18
Na_2O	1.05	1.20	1.12	1.20	1.17	1.20	1.34	1.28	1.08	1.31
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Ratio: $\frac{\%\ \text{Silica}}{\%\ \text{Alumina}}$ =	1:2.09	1:1.11	1:1.87	1:1.11	1:1.68	1:1.11	1:1.45	1:1.14	1:3.21	1:1.23

TABLE 4.

Body No.	220	221	51	216	56	217	60	218	63	219
% Raw clay	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
% Calcined clay	....	....	20.0	8.5	25.0	8.5	30.0	8.5	35.0	5.0
% Total clay	50.0	50.0	70.0	58.5	75.0	58.5	80.0	58.5	85.0	55.0
% Flint	32.5	2.5	18.5	....	13.5	....	8.5	....	....	....
% Sillimanite	....	30.0	....	30.0	....	30.0	....	30.0	....	30.0
Coefficients of Expansion $\times 10^{-6}$.										
25–200° C.	6.2	2.9	6.1	3.1	4.1	3.1	4.7	3.1	3.2	3.4
200–400° C.	4.6	4.0	5.1	3.8	4.1	3.8	4.6	3.8	3.5	3.9
25–400° C.	5.3	3.5	5.5	3.5	4.1	3.5	4.7	5.5	3.3	3.7
Ratio: $\frac{\%\ \text{Silica}}{\%\ \text{Alumina}}$ =	1:2.09	1:1.11	1:1.87	1:1.11	1:1.88	1:1.11	1:1.45	1:1.14	1:3.21	1:1.23

It will be noted that as sillimanite replaces flint in the bodies lower in clay content the reduction in thermal expansion is much more marked than in those bodies in which the clay content is high. As the content of clay increases the difference becomes smaller. The final body, with 85 per cent of clay, is not improved by the sillimanite substitution. It is obvious, of course, that in such compositions the possible content of flint can only be small. There can be no doubt but that the flint is the greatest factor in causing increased thermal expansion, not only by virtue of the properties of the crystalline quartz, but also through the increase of the silica content of the body, *per se*.

Upon replacing the flint by any substance, more inert from this standpoint, whether it be calcined kaolin, sillimanite or some other material, the general effect is a decrease in the thermal expansion.

Conclusion.

Bodies high in clay substance show low thermal expansions. Variations in flint content within the narrow limits possible in such bodies do not indicate any decided lowering of the expansivity. As the clay content of porcelains is lowered and the amount of quartz becomes larger, its quantitative effect as regards thermal expansion becomes more marked. Any replacement of quartz by substances more inert from this standpoint will lower the expansivity and calcined kaolin may be as effective in this respect as sillimanite or other synthetic silicates. Bars made of the synthetically prepared sillimanite and burned to cone 26 showed lineal thermal coefficients of expansion as follows: 25–200° C = 2.7×10^{-6}, 200–400° C = 3.9×10^{-6} and 25–400° C = 3.3×10^{-6}.

BUREAU OF STANDARDS,
PITTSBURGH, PA.

FURTHER STUDIES ON PORCELAIN.[1]

By F. H. Riddle.

Previous work in this laboratory, concerned with the study of porcelains,[2] dealt with the consideration of the firing ranges of various compositions. Porcelain bodies of widely varying compositions were examined but the methods of preparation were kept constant throughout the work. The present study includes further variations in composition and also deals with different methods of preparation.

Effect of Small Additions of MgO and CaO.—The effect of introducing small quantities of the alkaline earths, including BaO, has been discussed at length in the article mentioned above. Considerable evidence is also available from the work of others.[3]

The present work was intended to trace the effect of the CaO and MgO upon the microstructures of the porcelains.

The base composition was as follows:

	Per cent.
Flint	37
Potash feldspar	18
Ball clay	6
Kaolin	39
	100

The kaolin consisted of equal parts of Florida, Georgia, N. Carolina and Delaware. The ball clay consisted of equal parts of Tennessee No. 5 and Kentucky No. 4. The fluxes were added for the purpose of lowering the maturing temperatures of those bodies containing a low percentage of feldspar as the only flux.

[1] By permission of the Director, Bureau of Standards.

[2] *J. Am. Ceram. Soc.*, **1**, 606 (1918).

[3] A. E. Hottinger, *Trans. Am. Ceram. Soc.*, **5**, 132 (1903). L. E. Barringer, *Ibid.*, **6**, 86 (1904). E. Ogden, *Ibid.*, **7**, 370 (1905). C. E. Jackson, *Ibid.*, **8**, 114 (1906). A. S. Watts, *Ibid.*, **10**, 265, 543; and **11**, 185 (1909). E. Orton, Jr., *Ibid.*, **10**, 543 (1908). H. Hope, *Ibid.*, **11**, 494 (1909). A. V. Bleininger and R. T. Stull, *Ibid.*, **12**, 628 (1910). L. Ogden, *Ibid.*, **13**, 395 (1911).

Although the fluxing value of feldspar cannot be considered equivalent to that of the alkaline earths used, for the sake of simplicity it was replaced by equal amounts of the other fluxes.

The four bodies examined petrographically were:

No. 164, containing 0.2 per cent MgO.
No. 167, containing 1.0 per cent MgO.
No. 168, containing 0.2 per cent CaO.
No. 171, containing 1.0 per cent CaO.

These percentage additions were, of course, not chemically equivalent—since the molecular proportion of MgO was greater than that of CaO.

Fig. 1 shows the temperature-porosity ranges of the extremes

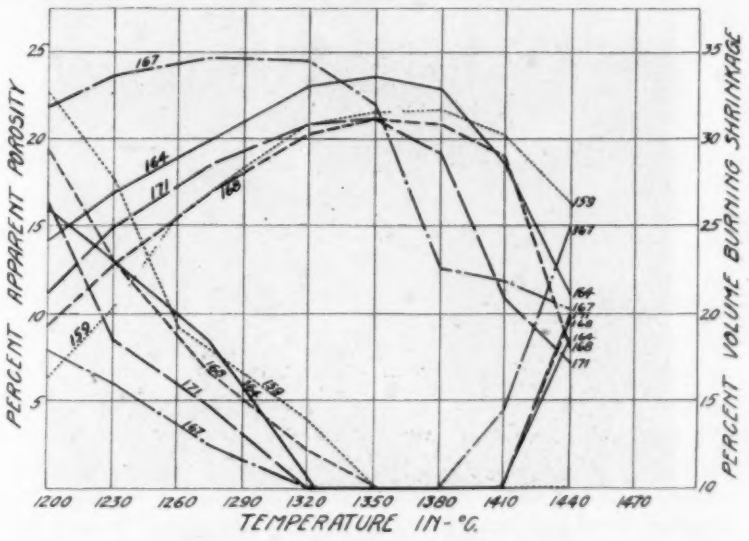


FIG. 1.

of the MgO- and CaO-series together with similar curves for body No. 159, having the same composition as the others but lacking the alkaline-earth fluxes. Without these additional fluxes the body requires a higher temperature to reach maturity. It will also be noted from the diagram that the maturing tempera-

ture of the body containing MgO is lower than that of the body containing CaO.

The five bodies in question show wide differences when examined microscopically in thin sections. The specimens examined under the microscope were fired together to the softening temperature of cone 14. Although this temperature is higher than is required to mature the bodies containing the alkaline earths, the sections show quite markedly the effect of the additions. From the photomicrographs of the sections (Figs. 2, 3, 4, 5 and 6), it appears that solution of the quartz grains has taken place to a varying extent and that the amount, distribution and size of the sillimanite crystals likewise show distinct differences.

The section of body 159, Fig. 2, indicates some solution of the

FIG. 2.—Body 159, cone 14 (200 diameters).

quartz grains around the corners and edges but it has not gone very far. The clay is entirely dissociated and the large original grains have become aggregates of numerous, long, slender crystals of sillimanite. The great majority of the crystals are smaller than 9μ (0.009 mm.), scarcely discernible as definite crystals. Some crystals of the size 9μ are to be found and a few between

9μ and 18μ. The glassy ground-mass has a cloudy appearance, presumably due to very minute crystallites of sillimanite derived from clay dissolved in the feldspar. The larger quartz grains show narrow zones of glass surrounding each particle.

From the section of body 164, Fig. 3, it appears that the struc-

FIG. 3.—Body 164, cone 14 (200 diameters).

ture is decidedly more glassy and the ground-mass apparently more homogeneous. Large aggregates of sillimanite crystals are infrequent. The crystals have become thicker but their lengths remain about the same. No great change is to be expected since the flux in the body probably does not penetrate the larger clay grains but simply dissolves their outer portions. The greater homogeneity of the ground-mass has been brought about by the nearly complete solution of the larger clay grains. Although in body 159 the sillimanite crystals in the glassy ground-mass were too minute for measurement, they have now increased in size until crystals 5μ in size are quite frequent. Many remain which are smaller and hardly measurable. There is a pronounced difference to be noted as regards the quartz grains, which show a general rounding of the corners as compared with the angular

appearance of the quartz in body 159. Minute quartz grains have disappeared.

The photomicrograph of body 167, Fig. 4, shows still more

FIG. 4.—Body 167, cone 14 (200 diameters).

extensive solution of the quartz. The same general lack of aggregates of sillimanite crystals is observed as in body 164, the groundmass is more glassy and the crystals imbedded in it are larger. The sillimanite crystals range in size from 21μ to 27μ in length down to sizes too small for measurement. The average length is about 11μ. Some of the larger crystals are sufficiently thick to show interference colors. Frequently the interlocking of the crystals takes on the peculiar lattice structure noted by Klein.[1] While the size of the crystals has increased their number has decreased. To this is due, apparently, the more glassy appearance of the section. The greater translucency of the body is probably due to this and also to the increase in glass, due to quartz-solution.

The microstructure of body 168, Fig. 5, is much the same in

[1] Bur. Standards, *Tech. Paper* 80.

appearance as body 164. Quartz-solution appears to have progressed further since the glassy zone is somewhat wider.

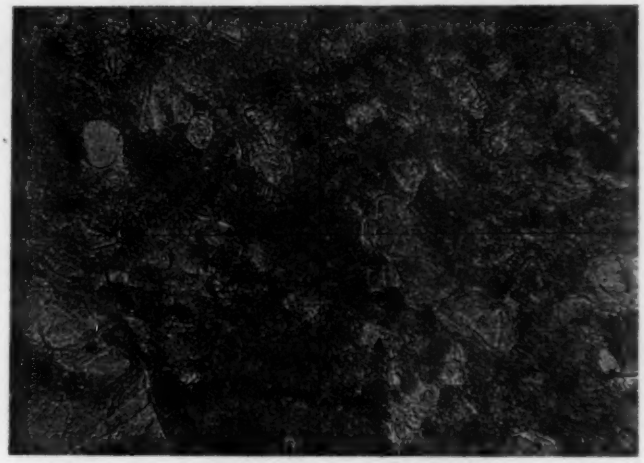


FIG. 5.—Body 168, cone 14 (200 diameters).

The section of body 171, Fig. 6, corresponds closely to that of body 167. Quartz-solution is slightly greater. The sillimanite crystals are a little larger, averaging 14μ.

It should be noted that both bodies, 167 and 171, are overfired. When burned to cone 11 they show considerable sillimanite formation but only a comparatively limited solution of quartz. They did not appear to have as good a structure as body 159 at cone 14, lacking in homogeneity. The bodies containing the alkaline-earth fluxes seem to be made up of an aggregate of quartz grains and decomposed clay substance cemented together by the glassy ground-masses.

The translucency of the bodies containing the MgO and CaO additions is as great at cone 11 as that of the body with only feldspar at cone 14, indicating that the amount of glass formed is increased.

A comparison of bodies 159, 168 and 171 shows that the use of CaO, like MgO, increases the sillimanite formation as well as the solution of the quartz, this being very probably due to the decreased viscosity of the body.

FIG. 6.—Body 171, cone 14 (200 diameters).

This observation differs from that of Watts,[1] although it must be understood that the bodies used were not the same nor, very likely, the conditions of firing.

Comparison between the Effect of Whiting and Dolomite.—It has been found that the addition of small amounts of dolomite to porcelains, maturing between cones 9 and 11, is effective in bringing about earlier vitrification. The action of dolomite is somewhat different from that of whiting and it is of interest to note this difference.

For the purpose of this part of the study a body somewhat similar to the type in use by American manufacturers of vitreous tableware was employed. Its composition was as follows:

[1] *J. Am. Ceram. Soc.*, **2**, 400 (1919).

	Per cent.
Flint	36
Potash feldspar	16
Tennessee ball clay No. 5	6
Florida kaolin	10
Delaware kaolin	9
English china clay	20
Dolomite or whiting, or both	3
	100

The only variation in the body was in the proportion of whiting to dolomite making up the total of 3 per cent. The proportions added were as follows:

TABLE 1.

No. of body.	Whiting. Per cent.	Dolomite. Per cent.
222	3.0	0.0
223	2.5	0.5
224	2.0	1.0
225	1.5	1.5
226	1.0	2.0
227	0.5	2.5
228	0.0	3.0

It is evident, of course, that these proportions are not molecularly equivalent, since the dolomite end of the series carries proportionately more flux than the whiting end.

The test pieces made from these bodies were fired at one time in a large gas fired test kiln, at a rate practically the same as that employed in firing commercial bisque-kilns. The temperature reached was that indicated by cone 11 and care was taken to prevent too rapid cooling. Discs were also made of the bodies, bisqued to cone 1, glazed, and fired to cone 11 down.

The seven fired bodies were subjected to tests for the purpose of determining their color, translucency, toughness, absorption, porosity, microstructure and crushing strength. The size and shape of the specimens needs no description. It might be stated, however, that for the estimation of the toughness of the bodies, pieces measuring 2″ in length and $^{7}/_{8}$″ in depth and width, in the fired state, were used.

Color.—All of the bodies were of excellent color and it would

be difficult to state definitely which end of the series was superior in this respect. Perhaps the color of the dolomite end was slightly richer in tone than the whiting end of the series.

Translucency.—All bodies, when made up into saucers of 2 gage thickness and fired (glazed) at cone 11, were very translucent. There was very little difference in this respect, although the dolomite end of the series showed somewhat greater translucency. All of the bodies had a fine appearance.

Toughness.—This quality was determined by means of the rattler test which has been used by others[1] but for which no standard has been adopted. The specimens used by us were made with square edges and corners and were of such size that they could be tested in an ordinary ball mill. The sharp edges were found to be a very desirable feature, inasmuch as they afforded an opportunity for the chipping of brittle bodies during the first half-hour of the run. This loss in weight is very significant and more representative of the actual behavior of the body than the total loss after a run of longer duration, since, after the corners are worn down, the specimens are worn down more by attrition than by impact. For this reason rounded specimens are not desirable. For table ware we are more interested in toughness, as evidenced by resistance to chipping, than in resistance to abrasion.

The rattler tests were made in a ball mill, $9^3/_4''$ in diameter and $13''$ long, inside, rotating at a speed of 40 revolutions per minute. The charge was made up of 61 pebbles of nearly uniform size, weighing 22 pounds and 12 ounces.

For each test, 13 porcelain specimens were used. If the tests were to be standardized it would, of course, be advisable to use, say, 10 kg. of pebbles and 12 specimens. The results of the tests made on bodies 222 to 226 are comparable throughout since the same conditions were maintained. The mill was stopped at time intervals of 15, 30, 60, 120 and 180 minutes and the specimens weighed. The losses in weight, expressed in per cent of the original weights of the charges, are given in the following tables:

[1] Watts, *Trans. Am. Ceram. Soc.*, 1, 86 (1899). E. Ogden, *Ibid.*, 7, 370 (1905).

TABLE 2.

Percentage Loss.

Body No.	15 Minutes.	30 Minutes.	60 Minutes.	120 Minutes.	180 Minutes.
222	4.67	6.38	7.86	9.86	11.25
223	4.09	5.60	7.72	10.45	11.40
224	4.47	5.98	9.20	11.10	12.80
225	2.95	4.60	7.00	8.80	9.42
226	3.66	5.20	7.00	9.45	10.70
227	3.60	5.15	6.85	8.70	9.80
228	3.05	4.12	5.80	8.40	10.30

The losses in weight in rattling are also shown in the curve of Fig. 7. It will be noted that as a whole the relations are fairly

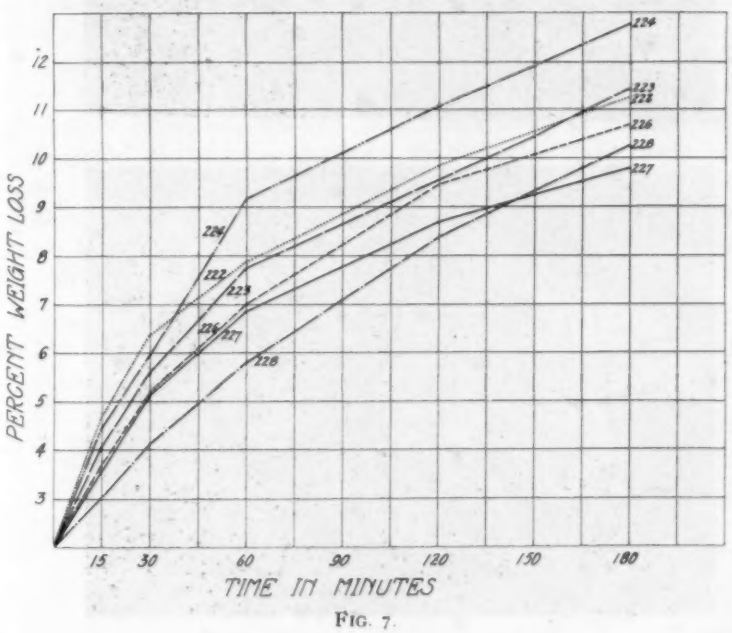
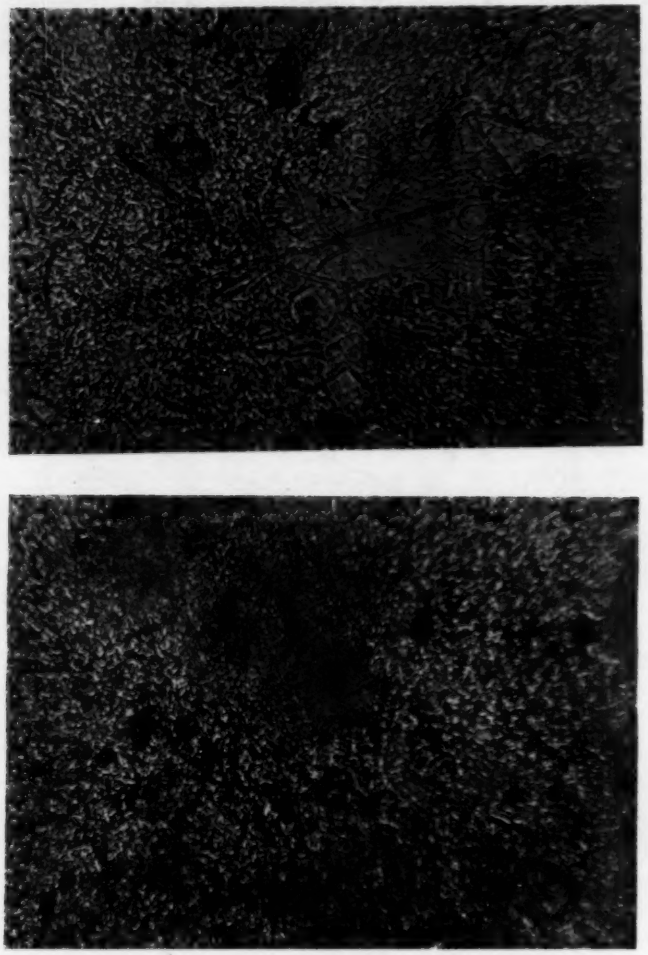


FIG. 7.

consistent. No great differences are to be found after the first part of the run nor at the end of the test. It is evident, therefore, that the toughness is nearly of the same magnitude for all

of the bodies. Still, the high-whiting end of the series shows more loss due to chipping than the dolomite end and, with the



Body 228.

Body 222.

FIG. 8.—Cone 11 (300 diameters).

exception of body 225, the loss decreases almost directly with the decrease in whiting. While this evidence tends to show that dolomite is productive of greater toughness it also seems

apparent that the lime bodies are somewhat harder, since they were worn less after the chipping stage during the first part of the run had been passed. This is noticeable from the gradual dropping off of the loss curve, particularly of the curves for bodies 222 and 228. The variation is not sufficiently striking to warrant making a positive generalization.

Microstructure.—Inspection of the bodies showed that the higher the content of whiting the more dense and vitreous the structure appeared to be. The high-dolomite end appears to be much more crystalline and breaks with a rough fracture, like sugar.

The characteristic structure may be compared by examining the microsections of bodies 222 and 228, representing the whiting and dolomite ends of the series, respectively (see Fig. 8).

Considering the fact that these bodies were fired to cone 11, it is noted that the solution of the quartz and the formation of sillimanite are well advanced. Body 222 shows a more nearly homogeneous structure and comparatively little well-defined crystalline sillimanite, though there undoubtedly is an appreciable amount of the latter present. On the other hand, body 228 shows a considerable amount of well-crystallized sillimanite, evident from the appearance of the coarser fractures and its lower loss in the rattler test. The solution of the quartz is similar in both cases.

Compressive Strength.—Cylindrical specimens of the members of this series were subjected to crushing tests with the following results:

Body No.	Lbs. per sq. inch.
222	57,500
223	38,700
224	49,100
225	55,800
226	46,200
227	55,700
228	55,600
Average,	51,228

It will be noted that the highest strength is obtained with the use of whiting alone, but that the variations in values of this

kind are so great that we can only say that there is no marked differences between the extremes. The crushing values obtained were quite high in all cases and fully equal to strengths of commercial porcelains.

It would seem, therefore, that the use of dolomite in replacing whiting, wholly or partially, is justified, especially in producing bodies of superior toughness or resistance to chipping, such as table ware. Its low cost is an additional point in its favor.

Effect of Fine Grinding.—The question as to the effect of longer or shorter wet grinding is still a more or less mooted one. While some advocate long grinding, others are of the opinion that the best results are obtained with shorter grinding.

The bodies discussed in previous paragraphs were ground for three hours in ball mills $9^3/_4''$ in diameter and $13''$ long, inside, rotating at a speed of 40 revolutions per minute. Five kilograms of charge were ground in each mill. It was thought desirable to study the effect of longer grinding with reference to the effect upon the content of plasticity water, drying and burning shrinkage and porosity changes.

The body selected for this work had the composition:

	Per cent.
Kentucky ball clay No. 4	4.00
Tennessee ball clay No. 5	4.00
Florida kaolin	9.25
Delaware kaolin	9.25
Georgia kaolin	9.25
N. Carolina kaolin	9.25
Feldspar	18.00
Flint	37.00
	100.00

This body when ground for three hours was numbered 159; 6 hours grinding, 160; 12 hours, 161; 24 hours, 162; and 48 hours, 163.

Test specimens were prepared in the usual way and fired to maturity. The water of plasticity and the drying shrinkages, expressed in terms of the dry volumes, were found to be as follows:

TABLE 3.

No. of body.	Per cent water.	Per cent volume drying shrinkage.
159	28.50	15.77
160	28.20	14.20
161	29.63	14.75
162	31.85	15.90
163	34.40	16.73

It is evident that the water of plasticity and with it the drying shrinkage are increased by longer grinding. The difference is not marked up to 24 hours, but after that it becomes quite apparent. It is quite probable that grinding for too long a time is very apt to give a body of unsatisfactory working behavior, especially in large cylinders where the grinding effect is very much more intense and where even one additional hour may bring about a considerable change.

The porosity and volume changes undergone by the body ground for different periods of time are given in Table 4 and shown graphically in Fig. 9.

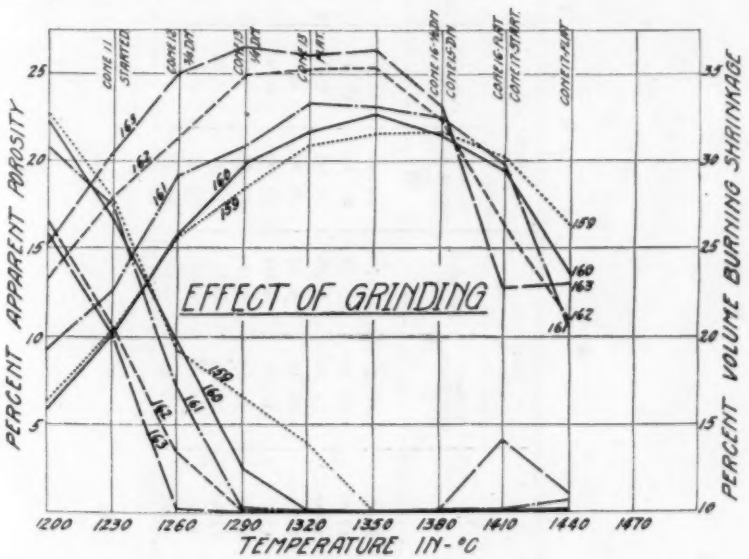


FIG. 9.

TABLE 4.

°C.	Body 159. 3 hrs. grinding.		Body 160. 6 hrs. grinding.		Body 161. 12 hrs. grinding.		Body 162. 24 hrs. grinding.		Body 163. 48 hrs. grinding.	
	Volume shrinkage. %.	Porosity. %.	Volume shrinkage. %.	Porosity. %.	Volume shrinkage. %.	Porosity. %.	Volume shrinkage. %.	Porosity. %.	Volume shrinkage. %.	Porosity. %.
1200	16.48	22.70	15.92	22.20	19.48	20.85	23.30	16.55	25.20	15.82
1230	20.30	17.75	20.15	16.75	22.70	17.45	27.95	10.88	30.50	10.40
1260	25.50	9.36	25.65	9.87	29.10	7.21	28.50	3.50	35.00	0.05
1290	28.40	9.24	29.85	2.39	31.90	0.08	34.95	0.0	36.55	0.0
1310	30.82	4.02	31.60	0.08	33.30	0.0	35.05	0.0	36.00	0.0
1340	31.63	0.0	32.55	0.0	33.18	0.0	35.15	0.0	36.30	0.0
1370	31.65	0.0	31.55	0.0	32.60	0.0	32.35	0.0	33.12	0.0
1410	30.10	0.0	29.30	0.0	29.80	0.0	26.42	0.0	22.87	4.15
1440	26.42	0.0	23.32	0.0	20.60	0.0	20.90	0.0	23.05	1.10

The fact that finer grinding causes earlier maturity and earlier overfiring is brought out very strikingly. The body when ground three hours matured at 1340° C, and the same body, ground 48 hours, reached zero absorption at 1290°, a difference of about 50°. The intermediate grinds mature quite regularly in proportion to the time of grinding. It would seem, then, that the effect of longer grinding is equivalent to an increase in feldspar or other fluxes or in ball clay. It appears also that longer grinding may be practiced with bodies low in ball clay in order to reach the desired degree of maturity which otherwise would require a higher content of this constituent. The petrographic inspection of the bodies ground for different periods of time revealed no essential differences in the microstructures.

The writer is indebted to Mr. A. B. Peck for valuable assistance in the preparation and examination of the thin sections, also to Mr. A. V. Bleininger and members of the Clay Products Section of the Bureau of Standards.

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THE REHYDRATION OF CALCINED CLAYS.

By J. S. Laird and R. F. Geller.

Introduction.

It has been shown by Mellor,[1] Sokolov,[2] Bleininger,[3] Brown and Montgomery,[4] and others that while clays and kaolins do not appear to have a definite decomposition temperature, there is little loss of water on heating them to temperatures below 500–600° C, but that heating them to higher temperatures for a sufficient time causes complete dehydration. In the case of plastic clays the plasticity diminishes as a rule as they are dehydrated, and disappears completely on heating to a red heat, while a much coarser, granular texture is developed in the clays.

That there is little tendency towards the recombination of water with calcined clay is shown by the prolonged resistance to weathering of even very soft-burned clay products, when not subject to frost action or containing soluble salts. Reported analyses of pieces of very old soft-burned pottery show sometimes as high as 3 per cent water. Calcined clay absorbs from moist air considerable hygroscopic water; according to Stull[5] upwards of 5 per cent in the case of graphite-clay crucibles. This hygroscopic water is driven off by drying at 110–120° C. Hornung[6] has shown that a surface clay, calcined at any temperature below 900° C, when kept in water for two weeks took up small amounts of water not capable of being driven off at 110° C, and, therefore, apparently chemically combined. The amount taken up reached a maximum of 1 per cent in the case of a sample partially dehydrated by being heated to only 350° C. Mellor and Holdcroft,[7] in an investiga-

[1] Mellor and Holdcroft, *Trans. Eng. Ceram. Soc.*, **9**, 94 (1911).

[2] Sokolov, *Z. Kryst. Mineralog.*, **55**, 195–6 (1917).

[3] A. V. Bleininger, Bur. of Standards, *Tech. Paper* 1.

[4] G. H. Brown and E. T. Montgomery, *Trans. Am. Ceram. Soc.*, **14**, 709 (1912).

[5] R. T. Stull, *J. Am. Ceram. Soc.*, **2**, 209 (1919).

[6] M. R. Hornung, Thesis, University of Illinois.

[7] Mellor and Holdcroft, *Trans. Eng. Ceram. Soc.*, **10**, 169 (1912).

tion of the chemical constitution of the kaolinite molecule, attempted to rehydrate kaolin which had been calcined at 600–640° C, by heating it in water under pressure to 300° C. Under this treatment the kaolin took up only 2.5 per cent water and did not become plastic. They ascribed the water taken into combination to hydration of free silica, and concluded that on dehydration the

$$O = Al - O - Si = O$$

kaolinite did not give the anhydride $\quad > O$

$$O = Al - O - Si = O$$

but decomposed into free silica and alumina.

In the hope of devising a method of increasing the plasticity of certain non-plastic or slightly plastic clays, we have studied the action of very hot water, necessarily under very high pressures, upon a number of raw and calcined clays and kaolins. We have found that such treatment has little or no effect upon raw clays, but that clays calcined at moderate temperatures can be very largely rehydrated—the rehydrated clay in general showing considerable plasticity.

Experimental.

The treatment of the clays was carried on in high-pressure autoclaves or "vulcanizers," of which the largest had a capacity of about one gallon, and was built to withstand steam pressures up to 1000 pounds per square inch, corresponding to a temperature of about 290° C. The samples treated were in amounts up to several pounds in weight, so that their plasticities, or at least their bonding powers, could be determined by making ordinary tension briquettes and noting their air-dried strengths. The steam pressures were measured by an ordinary pressure gauge, and the temperatures by a mercury thermometer inserted in a well in the cover of the autoclave. The water content of the sample was determined as loss on ignition at 900° C in an electric muffle-furnace, after drying to constant weight in an oven at 110–120° C.

Considerable difficulty was encountered in carrying out the experiments at high pressures, as the autoclaves were not satisfactorily designed for such service. In particular there was difficulty in making a tight gasket-joint between the body and

cover of the autoclave. Soft lead, melted and poured into the gasket groove, formed the most satisfactory packing.

As the action seemed to be a surface one, wet-grinding of samples for periods of 24–48 hours was resorted to in order to decrease the size of the particles and increase the surfaces exposed. It seems probable that the action would be much more rapid if the material could be simultaneously subjected to grinding and treatment in a suitably designed rotary autoclave.

Results.

Pennsylvania Flint Clay:

(A) Coarse lumps of the raw clay were not affected by being heated in water to 200–250° C for a very long time, no slaking being observed after 200 hours. Water-ground samples seemed somewhat more plastic after treatment at 90 pounds for 48 hours.

(B) Calcined at 800° C; loss on ignition 15.05 per cent, residual 0.4 per cent. Coarsely ground samples were apparently not affected by the treatment. After wet-grinding 24 hours and treating in water at 255° C for 30 hours, the clay took up 10.9 per cent water, which was increased by repeating the process to 11.7 per cent. Air-dried strength 52 pounds. When only a moderate amount of water was used with this clay it appeared to set on cooling after removal from the autoclave. This peculiar behavior was not shown by any other clay tested. In order to verify it briquettes of the clay mixed with an equal amount of Ottawa sand were hydrated in the steam space above the water to avoid mechanical disintegration. A tensile strength of 360 pounds per sq. in. was developed on heating to 230° C for 24 hours.

Kittanning Stoneware Clay.—Original water content 8.4 per cent.

(A) Calcined at 600° C one hour; residual water 4.9 per cent; loss 3.5 per cent. Heated in water to 150° C 36 hours; water content 7.5 per cent.

(B) Calcined at 700° C; residual water 1.48 per cent. Heated in water to 230° C 17 hours; water content 7.8 per cent. Heated in water to 230° C 16 hours; water content 6.5 per cent.

(C) Calcined at 800° C; residual water 0.27 per cent. Heated in water to 250° C 48 hours; water content 6.04 per cent. The clay was fairly plastic after treatment.

Florida Kaolin.—Original water content, 13.78 per cent.

Calcined at 600° C; residual water 1.96 per cent. Heated in water to 270° C for 8 hours; water content 11.0 per cent. The clay was fairly plastic after treatment, but rather short and sticky like the raw clay.

Georgia Kaolin.—Original water content 12.06 per cent. Calcined at 700° C; residual water 0.8 per cent.

(A) Heated in water to 270° C for 9 hours; water content 2.34 per cent.

(B) Wet ground and heated as in (A); water content 3.29 per cent.

(C) Heated as in (B) for 9 hours more to 270° C; water content 4.00 per cent.

White-Ware Bisque.—Original water content 0.13 per cent.

Water ground and heated in water to 270° C for 8 hours; water content 0.6 per cent. The material did not become plastic and the coarse-ground material was not slaked by the treatment.

Conclusions.

As a result of the experimental work which has been done we may conclude that:

1. Flint clay cannot be slaked by the action of very hot water in any reasonable length of time, and the plasticities of raw clays are little affected by such action.

2. Clays which have been almost completely dehydrated by calcination at a moderate temperature, 600–700° C, can be rehydrated by being heated in water to temperatures of 200–270° C for a sufficient length of time (8–48 hours). The rehydrated material is in general plastic and appears colloidal. After being worked up and dried two or three times it resembles a raw clay.

3. Clays which have been calcined at higher temperatures can be rehydrated only much more slowly and incompletely.

4. From the ease with which clays dehydrated at a moderate temperature can be rehydrated and brought back to practically their original condition, it seems probable that on dehydration kaolinite forms an anhydride which is broken down by other reactions upon heating to higher temperatures, such as the formation of sillimanite.

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APPARENT VS. TRUE SPECIFIC GRAVITY OF SILICA BRICKS.

By Leon R. Office.

The author, in collaboration with Mr. R. J. Montgomery, submitted a paper at the 1918 meeting of the American Ceramic Society on "Laboratory Testing of Silica Brick."[1] In that paper the importance of the specific-gravity determination was brought out, particularly in control work for the detection of under-burned brick.

Owing to the large amount of silica refractories in a battery of coke ovens, it is at once apparent that it is of the utmost importance to have the bricks and shapes well burned, with as much permanent expansion removed as possible. When the bricks are shipped in large quantities it is necessary to have a method that is both simple and quick to detect under-burning, and at the same time one which can be relied upon. The method employed by us was that of taking a 10-gram chip from the brick and boiling in water for one hour, using a Westphal balance for the weighings. The test required that chips from the same sample check within 0.02.

In a discussion of the author's paper, Mr. D. W. Ross[2] was of the opinion that better results could be obtained by subjecting the specimens to a vacuum while immersed in hot water. Mr. R. M. Howe[3] also presented some interesting data showing determinations under vacuum.

To test out the accuracy of the Westphal-balance method with small chips, several brands of silica bricks were obtained from various parts of the country. These brands covered a range from extremely soft-burned to hard-burned bricks. Two chips were taken from each brick and the apparent specific gravity obtained by careful weighing to the third decimal place. The samples

[1] *J. Am. Ceram. Soc.*, **1**, 338 (1918).

[2] *Loc. cit.*, p. 349.

[3] *Ibid.*, p. 346.

were boiled in distilled water for one hour. After its apparent specific gravity had been recorded, each chip was ground in an agate mortar to pass a 100-mesh sieve. All samples, both before and after grinding, were dried at 110° C for several hours and cooled before the tests were made.

The true specific gravity of each powdered sample was obtained

TABLE 1.

Sample No.	Burn.	State.	Apparent sp. gr.	True sp. gr.	Difference.
5984-A	Hard	Penna.	2.265	2.331	+0.066
B	Hard	Penna.	2.285	2.317	+0.032
6094-A	Medium	Penna.	2.461	2.466	+0.005
B	Medium	Penna.	2.461	2.469	+0.008
1997-A	Hard	Penna.	2.320	2.346	+0.026
B[1]	.....	.....	...	...	...
1996-A	Medium	Penna.	2.464	2.467	+0.003
B	Medium	Penna.	2.467	2.471	+0.004
1995-A	Soft	Penna.	2.487	2.482	—0.005
B	Soft	Penna.	2.515	2.511	—0.004
6360-A	Hard	Penna.	2.296	2.329	+0.033
B	Hard	Penna.	2.300	2.321	+0.021
WH-A	Soft	Penna.	2.555	2.557	+0.002
B	Soft	Penna.	2.551	2.557	+0.006
2616-A	Hard	Ill.	2.316	2.316	+0.000
B	Hard	Ill.	2.319	2.321	+0.002
6537-A	Hard	Ill.	2.395	2.417	+0.022
B	Hard	Ill.	2.386	2.411	+0.025
6368-A	Medium	Ill.	2.432	2.437	+0.005
B	Medium	Ill.	2.431	2.436	+0.005
S_2-A	Hard	Colo.	2.384	2.384	+0.000
B	Hard	Colo.	2.389	2.392	+0.003
D_2-A	Soft	Colo.	2.524	2.528	+0.004
B	Soft	Colo.	2.530	2.529	—0.001
6535-A	Medium	Canada	2.478	2.491	+0.013
B	Medium	Canada	2.492	2.493	+0.001
6536-A	Medium	Canada	2.491	2.494	+0.003
B	Medium	Canada	2.496	2.497	+0.001
					Av., +0.011

[1] Sample destroyed.

by the refined method of Day and Allen.[1] A pycnometer with thermometer and capillary side-arm attached was used. The pycnometer with its charge was placed in water at 80° to 90° C and attached to a suction line for one-half hour to remove entrapped air. Table No. 1 gives the results of the tests with two chips from each brick. The brands are not given but the state in which they are manufactured is indicated. Eight distinct brands and seven manufacturers are represented.

Summary.

Of 27 samples tested 22 showed a slightly higher, two the same, and three a lower true specific gravity.

By taking an average of the differences, the true specific gravity is found to be 0.011 higher than the apparent specific gravity.

If care is taken to obtain two 10-gram chips as representative as possible of the material in a silica brick, and if their respective specific gravities check within 0.02, the result should be very close to the true specific gravity.

LABORATORIES OF THE KOPPERS COMPANY AND
PITTSBURGH BY-PRODUCT COKE COMPANY,
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[1] "The Analysis of Silicate and Carbonate Rocks," U. S. Geol. Surv., *Bull.* **422**.

CERAMIC ABSTRACTS.

General.

On the employment of the Brinell ball for testing construction materials. M. M. H. Le Chatelier and B. Bogitch. *La Ceramique*, **371**, 17–18 (1919).—The use of the Brinell hardness test for construction materials has certain advantages over the compression test, namely, it is rapid, accurate and more economical than the compression test. For this test a steel ball, 17.5 mm. in diameter, is used with a pressure of 500 kilograms for 1 minute. The diameter of the depression is then measured under a microscope and expressed in mm. The diameter in copper is 4.5 and in lead 10.1. Testing various construction materials by this method gave the following results which check fairly closely:

	Per cent variation.
Fire clay brick—6.0, 6.1, 6.0, 6.1, 6.2.....	3.3
Hard silica brick—5.1, 5.0, 5.1, 5.0, 5.0...	2.0
Tender silica brick—10.1, 10.7, 10.6, 10.6.	3.0
Plaster—10.3, 10.3.....	0.0
Limestone—5.8, 5.8,.....	0.0
Cement mortar—7.0, 7.1.....	1.5

Compression tests made of the same silica brick cut into cubes, 2 cm. on each side, showed a variation which was much greater as follows:

Hard brick—188, 240, 200.
Soft brick—108, 132, 182.

The Brinell test permits a study of the structures of bricks which often varies much on the same brick as follows:

Hard face brick, 4.5, 5.2, 8.3, 6.3, 8.8.
Soft face brick, 8.4, 6.8, 10.4, 8.3, 12.0.

Tests made on different bricks varied as follows:

	Piston side.	Bottom side.
Brick No. 1.....	5.4	5.6
Brick No. 2.....	5.6	5.6
Brick No. 3.....	5.9	6.3

The Brinell testing machine has an advantage in that it is portable and permits of direct control of products in their manufacture.

H. G. Schurecht.

The casting of heavy clay pottery. B. J. Allen. The Ceramic Society. *Pottery Gazette*, 489–496 (1919).—Casting by means of cored molds produces

hollow castings and poor structure. By resorting to casting under pressure, by means of molds with air-tight casings and connected to an air pump, capable of removing the air from the space between the plaster and the casing, the clay could be kept in contact with the plaster and the water extraction from the slip be made to continue until the desired result was obtained. Methods were described for applying pressure to the slip-supply in producing pieces of unusual thickness and pieces with tapering sides and it was shown how, by application of pressure to the slip, the slip could be applied to the thick parts before the thinner parts were hard. A mold of this type with a core may be used for lining the insides of pots with special materials, *e. g.*, zirconium, by first dipping the core in a slip of zirconium. For casting covered pots the vacuum method is indispensable to perfect ware.

H. G. SCHURECHT.

Tunnel oven development in the potteries. By a MEMBER OF THE STAFF. *The Pottery Gazette* 714–717 (1919).—English potters are coming to the conclusion that tunnel-oven firing is likely to offer a solution of some of their difficulties, especially in saving fuel. A tunnel kiln at La Louiviére, Belgium, which is 210 feet long, is described. Trucks of glost ware pass two at a time at the rate of five feet every 35 minutes. This kiln has been in operation continuously for $2^1/_2$ years without once stopping for repairs. A manufacturer at Stoke-on-Trent who is using a Dressler kiln gives the following data: 30 tons of fuel are used per week to effect an output equivalent to 6 ordinary round periodic kilns which utilize 81 tons. Economy in labor amounts to 23 pounds per week. Truck repairs, etc., cost 15 pounds as compared with 49 pounds necessary to keep up sagger repairs, etc., in periodic kilns. The Marlow tunnel kiln of the muffle type is described. A perforated tunnel, at a certain distance from the firing zone, is covered with a second arch, a cavity being left between the two. The hot air rises after passing the hottest zone and is returned into a heat conduit or combustion chamber, thereby reducing the fuel consumption $33^1/_3\%$. H. G. SCHURECHT.

The English Ceramic Society. *The Pottery Gazette*, No. 506, 836–840 (1919).—At a meeting of the Refractory Section of the Ceramic Society held at Middlesbroug the following papers were read:

"The Geology of the Refractory Materials of the North of England," Atkinson and Stobbs. 22% of the fire clay used in England comes from the north of England.

"Mica Schists for Lining Cupolas and Steel Converters," P. Boswell. Certain rocks of the mica schist group from near Philadelphia are employed as a furnace lining in a large number of American foundries. In the discussion which followed it was stated that in using natural products for furnace linings minimum spalling and chipping were obtained by placing the foliated planes in one particular direction.

"The Corrosion of Coke Oven Walls," W. J. Rees. Sodium sulphate and sodium chloride in coal may cause corrosion of oven walls. These and other salts may be removed by washing the coal.

"Some Criticisms by a Fire Brick Manufacturer," G. Chance. Fire brick users are unreasonable in the following ways: (1) Low prices are demanded rather than quality. (2) Users do not give the manufacturer sufficient time to make brick properly. (3) Users will not try a new brand of brick. (4) Some users like to see iron specks on brick while others do not.

"Factors Influencing the Properties of Silica Brick," Dr. Scott. Effect of magnesia, alumina, iron oxide, iron oxide plus carbon, and titanic oxide were studied. Smallest after-expansions were obtained by using a bond of lime and iron oxide, while the lowest expansions were obtained by using these oxides separately.

"Note on a Silica Brick from a Furnace Row," J. E. Stead. A brick 3 wide before it was put in an open hearth furnace measured $2^1/_2$ at one end and $2^3/_8$ at the other end after it had been in use.

"A New Type of Recuperative Furnace," Walter Rosenhain and E. Coad-Pryor. An experimental furnace for melting glass and for firing refractories at high temperatures was described. The only form of recuperator furnace giving promise was one consisting of a nest or battery of tubes made of a silicon carbide and china clay mixture, through which the incoming air could be drawn while the products of combustion circulated about the exterior tubes. Fire-clay tubes would not stand the test.

"Further Notes on Zinc-Furnace Refractories," J. A Audley. Mülhaeuser was extensively quoted and according to this writer it was shown that the gradual vitrification of parts of muffle walls (especially bottoms) was accompanied by a decrease in refractoriness and resistance to sudden temperature change, but increased the strength, elasticity and extensibility, so that the average life of the muffles was sixty-three days. The use of zirconia as a coating was referred to, but the small contraction of this material would make it hard to fit a body. Applying the zirconia by putting on a number of coatings, each containing an increased amount of zirconia, is suggested. H. G. SCHURECHT.

Zirconia, its utilization as a refractory, an opacifier and an abrasive. M. A. GRANGER. *Mineral Foote Notes, 3*, Nos. 7 and 8 (1919).—Brazilian zirconia deposits at Pocas de Caldas are very extensive and contain 73–74% zirconium. Softening point of pure zirconia is 3000° C. Even with 1.25% silica and iron oxide it does not fuse below 2500° C. The thermal conductivity of the fused pure material is very low. Its coefficient of distillation is low (8.4×10^{-7}), which compares favorably with that of carborundum (7.58×10^{-6}) or alundum (7.10×10^{-6}). It is very resistant to abrupt changes of temperature and is chemically inert. Zirconium carbide forms easily when zirconia is heated to a high temp. in contact with carbon the crucibles often becoming destroyed thereby. Specific conductivity of zirconia is 0.0008 at 1200° C and 0.0034 at 1400° C. Dr. Rieke (*Sprechsaal*, **1908**, 214), published the first researches on the use of zirconia as a refractory. The following methods for purifying zirconia are described: (1) Treatment with hydrofluoric

acid; (2) Transformation into carbide; (3) Treatment with sulphuric acid or bisulphates; and (4) Alkaline fusion. For practical purposes treatment with hydrochloric acid is sufficient. In the manufacture of zirconia crucibles zirconium hydrate has been tried as a binder. The vessels, however, were too fragile and another binder was sought. Starch intimately mixed with zirconium hydrate and allowed to dry in air until it contained 9–10% zirconia was especially desirable. Moistened plaster-molds, having a wooden core covered with foil, could be used to mold crucibles. Two hours after molding crucibles are removed from mold, dried, and finally burned to 2000–3000° C in an electric furnace. Experiments in Germany showed that a lining of zirconia lasts a long time, and that in spite of the higher initial cost there was a saving of 50%. In metallurgy zirconia could also be employed in the preparation of copper and its alloys. Silicate of soda and tar are used with zirconia in forming the linings in furnaces. Lime may also be used in small quantities with zirconia, giving good results. Zirconia for laboratory use may be purified as follows: After a preliminary treatment with HCl the mineral is heated on a sand bath with H_2SO_4. The solution is evaporated to dryness and taken up with water. Zirconia can then be removed as follows: The addition of potassium sulphate precipitates a double sulphate; the addition of ammonia precipitates hydrated zirconium; the calcination of hydrate or sulphate of zirconium gives zirconia. Zirconia can be used as an opacifier in glazes. Although it increases the cost of a glaze it produces one which is very acid resisting. Because of its hardness zircon has been used as an abrasive for grinding mother-of-pearl. Grindstones for this purpose are not fired but cemented together. H. G. SCHURECHT.

A visit to a Lancashire pottery. By a MEMBER OF THE STAFF. *Pottery Gazette*, No. 506, 828–830 (1919).—The Heaton Mersey Pottery near Manchester is described. A 12-chamber Hoffman kiln with a very tall chimney is used. The clay is blunged and screened and then one portion is dried in a series of drying kilns heated by exhaust gases from the kilns. Another portion is dried in open-air driers. In summer the clay is allowed to settle to a depth of 5″–6″ and taken off once a month. In winter the clay is allowed to settle 18 inches and is left for the whole winter. Clay dried in open-air driers is more plastic than that dried in slip kilns. The ware (flower pots, milk bowls, etc.) is thrown on a steam-driven throwing wheel. When "hard-green" a white engobe is applied. The pieces are then dipped in a blue, galena glaze. H. G. SCHURECHT.

Brick for roads. A. B. SEARLE. *The British Clayworker*, **27**, 102–106 (1919).—The structure of bricks should consist of a porous skeleton filled with a slag-like mass which can be observed under a microscope if thin sections one-thousandth of an inch are made. A section of some of the best and toughest road bricks, after immersion in hydrofluoric acid, yield a felted crystalline mass of impure sillimanite, which possesses great strength and

toughness. To reduce laminations the mouthpiece of the auger machine may be provided with two exits—one to either side of the auger shaft—thus avoiding the lamination due to the central shaft of the pug mill. Recent tests show that the strongest brick after drying were found to be those which had been heated to 240° F in an atmosphere saturated with moisture, and then allowed to dry slowly while the temperature was maintained constant. Brick set damp in the kiln are invariably softer than those which are properly dried. H. G. SCHURECHT.

Clay men make new building material. *Brick and Clay Record*, **55**, 484–487 (1919).—A new company, The American Aggregate Co., Kansas City, has been organized to make a light-weight aggregate from shale for cement. The aggregate is made in a continuous kiln by overburning shale. The temperature of burning is approximately 2000° F and the time required is about 2 hours. The aggregate is cooled slowly after burning in order to retain strength. Concrete with crushed stone aggregate weighs 140–155 lbs. per cubic foot. Where the bloated shale (Haydite) is used it weighs 90–100 lbs. per cubic foot. Tests made show that concrete made of this material is 30–40% stronger than when other aggregates are used. Its use for building dwellings, railroad cars and boats has been tried and found satisfactory—having the advantage of being cheap and resistant to weather. H. G. SCHURECHT.

Geological.

Magnesite, its occurrence and uses. By T. CROOK. *The Mining Magazine*, **20**, 115–120, 175–179, 246–249, 308–311 (1919).—The paper constitutes a reprint of an article entitled "Magnesite as a Raw Material," by T. Crook, of the Imperial Institute. Among the many interesting points considered may be mentioned the following: the mineralogy of magnesite and a classification of magnesites on the basis of texture and composition as follows: (1) Spathic breunnerite, example, Styrian, (2) Spathic magnesite, example, Quebec, Washington and Norwegian; (3) Compact magnesite, example, Grecian, Californian, Italian, Indian (Salem) and Australian; (4) Hydromagnesite, example, Atlin in British Columbia. The term "spathic" refers to the comparatively coarsely crystalline magnesites and breunnerites, the constituent grains of which show cleavage. Analyses which show the range in composition of the various types are given. In this connection it is interesting to note that the material from Washington contains not more than 2% of lime while Quebec magnesite contains a considerable amount of dolomite and ranges up to 10% or more of lime. The various types are considered in detail and with respect to their occurrence both geographically and geologically. Comparisons of types are made and throughout the article are analyses of materials from various localities. In connection with the different types the uses of the raw material are mentioned. E. D. ELSTON.

Biennial Report of the State Geologist (1919). *Missouri Bureau of Geology and Mines.*—The report contains brief notes on the occurrence and production of fire clays and diaspore clays and lists of producers of clays and clay products are given. One analysis of diaspore clay is stated as follows: moisture = 0.60%; loss on ignition = 14.00%; silica (SiO_2) = 9.30%; alumina (Al_2O_3) = 73.73%; iron oxide (Fe_2O_3) = 0.57%; soda = 2.00%; potash (K_2O) = 0.52%. Brief statements concerning the occurrence and production of barytes, together with a directory of producers, are included.

E. D. ELSTON.

Refractory clay from Mattagami River. *Twenty-seventh Annual Report. Ontario Bur. of Mines,* Part 1 (1918).—Deposits of highly refractory, excellent, white fire clay have been discovered on Mattagami River opposite an island at the foot of the Long Portage. The material was tested by Mr. J. Keele of the Mines Department, Ottawa, and was pronounced by him to be one of the most refractory clays yet found in Canada. Furthermore, this clay is stated by Keele to be suitable for sanitary porcelain, vitrified floor tiles and wall tiles, and probably electrical porcelain. A red clay found on the same property proved to be semi-refractory in character and would probably make good fire brick when mixed with the white fire clay in the proportions of one part red clay with two parts of white clay. These deposits, however, are far from the railroad lines. E. D. ELSTON.

Refractories.

The Ceramic Society. *Pottery Gazette,* No. 503, 489–496 (1919).—At the monthly meeting of the English Ceramic Society, held April 14, the following papers were read:

"The Corrosive Action of Frits on Refractories," by R. L. Johnson. The method of making slagging tests by placing slag in holes, drilled in brick, is not satisfactory because the protective coating on the brick is destroyed by drilling. Using china rings on the surface of brick and putting frit in them was found to give more satisfactory results.

"The Substitution of Apatite for Bone Ash in China," by N. B. Davies. Tests were made to substitute Canadian apatite for bone ash. The following bodies were used:

	No. 1.	No. 2.	No. 3.	No. 4.
Apatite.....	42%	39%	35%	32%
Feldspar.....	15	16	17	19
China clay.....	33	34	34	35
Flint.....	10	11	14	14

All bodies had excellent casting and working properties. Greatest translucency was attained in body 4 at cone 9. The ware had a slight greenish tinge. In the discussion which followed it was stated that ware made from similar bodies lost their shape in burning.

"The Heat Conductivity of Porous Materials and Heat Insulation of Kilns," by Dr. J. W. Mellor. In calculations as to the rate of heat travel through a solid body and across adjacent air space with solids of different sizes, the author found that with cubes having a side of 0.1 cm., at 1400° C, the amount of heat carried per second across the air space and across the solid is the same. If pore space is less than above, the temperature in the air space would be higher than that of the adjacent solid. If, however, the pore space were 0.5 cm., the temperature would be much lower, coming out at just about enamel kiln heat, showing that the insulating properties of the air were breaking. With a pore 0.5 cm., above 730° C the air was a poorer insulator than was a solid. Certain experiments to verify the calculated results are being conducted and will later be published in the Transactions.

H. G. SCHURECHT.

Notes on refractory materials. By a CORRESPONDENT. *The Pottery Gazette*, No. 505, 727–730 (1919).—For resistance to action of flue dust, etc., the bricks are protected either by actual fusion of the surface of special brick or by painting with a mixture of carborundum plus 10% of fire clay or silicate of soda. The resistance to slag action is much greater when the brick are made under high pressure than when made with low pressure. Brick made of bauxite clays are giving good results in ports of gas-fired furnaces and in the crown of an electric furnace. A vitrified glass pot is not corroded by glass but a non-vitrified pot is strongly attacked above 1200° C and therefore it is suggested that empty pots be burned to 1350° C. In making silica brick it has been found that brick made of fine-grained quartzites, with a cement of amorphous silica, are more readily inverted into cristobalite or trydimite than those made from coarse-grained quartzite. H. G. SCHURECHT.

Glass.

The use of lime in the glass industry. F. GELSTHARP. *Rock Products*, **22**, 30 (No. 18, 1919).—Manufacturers of bottles and pressed and blown wares have always preferred to use quicklime, CaO, and some prefer hydrated lime, $Ca(OH)_2$. The general impression of such users is that the quicklime and hydrated lime give them better melting conditions and a glass of better color than can be made by use of limestone. In recent years some of these manufacturers have been induced to use limestone and have been quite successful in producing a glass at least equal to that formerly produced from quicklime. For window and plate glass limestone has always been used. When an attempt was made to use quicklime or hydrated lime, trouble in melting was experienced unless special care was exercised in the mixing with the other materials and in frequent testing of the lime. For plate glass, limestone should contain not over 1.5% MgO, although the content may be higher if the rock is uniform in composition and certain changes are made in the glass mix to control the degree of viscosity of the glass. Variation in the MgO content affects the melting conditions and the uniformity of the

glass. MgO compared to CaO in chem. equivs. produces a glass less fluid under like conditions, but compared by weight causes little difference in fusibility. MgO tends to prevent devitrification and lowers the coefficient of expansion. Limestone for glass should be ground so that 100% passes a 10- or 12-mesh screen and 90% passes 16-mesh, as this gives a degree of fineness that mixes well with the batch and gives a quick melt. The following are analyses of limestones from various localities and which have been found satisfactory for the several kinds of glass:

	SiO_2.	Fe_2O_3.	Al_2O_3.	$CaCO_3$.	$MgCO_3$.
1	1.00	0.13	0.05	97.81	1.01
2	0.23	0.10		98.12	1.55
3	0.60	0.05	0.08	98.56	0.71
4	0.50	0.14	0.04	89.07	10.25
5	0.84	0.06		98.60	0.50
6	0.44	0.26		98.50	0.80
7	0.94	0.10		98.05	0.91
8	0.08	0.02	0.12	99.25	0.53

The limestone must be as pure as possible, especially for the finer grades of glass. Al_2O_3 in the form of small amounts of calcareous shale will not give trouble, but in the form of ganister will give endless trouble by producing striae and stones. For plate glass, less than 0.10% Fe_2O_3 is desired and 0.15% is the maximum allowable. Dolomite limestone may be used in the glass batch. It is generally employed in the calcined form, and in tank furnaces where variations in the ratio of MgO to CaO can be more easily tolerated than where melting is done in pots as in the manufacture of plate glass. Chemical composition alone and not physical differences of the limestones affects the quality of the glass. F. A. KIRKPATRICK.

Enamels.

Acid test on enamels. W. D. COLLINS. *J. Ind. and Eng. Chem.*, **14**, 8 (1919).—Tests were made at the U. S. Bureau of Agriculture for acid resistance of 61 samples of enameled kitchen-ware from 26 American manufacturers. The principal test consisted of boiling 500 cc. 4 % acetic acid in the vessel for one-half hour. Some tests were also made with 1% tartaric and citric acids, the results of which corresponded to those obtained with 4% acetic acid. About half of the samples of white- and gray-ware suffered no loss of "glaze" on treatment with 4% acetic acid, while nearly all blue-ware was badly affected with 2% acetic acid. The amount of material dissolved in each case corresponded with the loss in "glaze." Seventeen samples from nine manufacturers gave no test for antimony. White and gray enamels contained about equal amounts of antimony according to tests, 34 out of 47 samples giving up 0.5 to 2.0 mg. of antimony when boiled with 4% acetic acid for 6 hours. Tests showed no antimony present in four blue enamels

tested. Lead was found in ware from only one manufacturer. Pieces of enamel chipped off several vessels under a heat treatment no more severe than might be received by any cooking vessel in use. R. R. DANIELSON.

Metallic coating for the rust-proofing of iron and steel. *Circular of the Bureau of Standards, No.* **80.**—Attempts to protect iron and steel against corrosion have led to the use of various materials for coatings, such as metallic coatings, oxide coatings, organic coatings such as paints and varnishes and vitreous enamels. This circular deals particularly with metallic coatings but contains much material of interest to those coating metals with other substances, such as vitreous enamels. The section on pickling and cleaning metals and the effects of these processes on the mechanical properties of steel will be of special interest to manufacturers of enameled wares. A well-selected and classified bibliography dealing with the general subject of corrosion is appended. HOMER F. STALEY.

Cement and Lime.

The Ternary System CaO–MgO–SiO_2. J. B. FERGUSON and H. E. MERWIN. *Am. J. Sci.*, **48**, 6 (Fourth Series) (1919).—The solidus-liquidus relations, the general behavior on heating to high temperatures and the properties of the compounds and solutions formed have now been determined for the four ternary systems CaO–Al_2O_3–SiO_2, CaO–MgO–Al_2O_3, MgO–Al_2O_3–SiO_2, CaO–MgO–SiO_2. These comprise the four possible ternary systems which can be formed from the oxides: CaO, MgO, Al_2O_3, SiO_2. The next step in this important series of investigations has been stated by the workers of the Geophysical Laboratory to be a study of the relations in the quaternary system CaO, MgO, Al_2O_3, SiO_2. In previous publications of the Geophysical Laboratory and of the American Ceramic Society applications of these results to ceramic problems such as the manufacture of Portland cement and of porcelain and other pottery wares have been made. The results should not, however, be used in these connections without the aid of data on the practical properties of the ceramic products. For example, the results of the above investigations indicate that in a certain type of porcelain, CaO would give a greater degree of fusion with like heat treatment than would MgO. From this it might be thought that CaO would give greater translucency than MgO. The reverse is true in this particular porcelain which is of the average American type. Other factors, possibly small amounts of other oxides, seem to govern the translucency more than does the supposedly greater fluxing action of the CaO. The relations found in the system CaO–MgO–SiO_2 are shown in Fig. 1. The wt. % compn. of any mixture of the three oxides is represented within the triangle. The proportion of any one oxide may be found by measuring the perpendicular distance from the point representing the mixture to the side opposite that representing the oxide, the total distance from the oxide apex to the opposite side being 100. For example, the % of SiO_2 in the mixture which happens to be represented by

the point designated $CaO.MgO.SiO_2$ may be read from the diagram as 38%. The areas bounded by the heavy full lines are called "fields" of stability of the oxide or compound designated for each. In the area or "field" designated as CaO, all mixtures when melted and then cooled slowly will crystallize out first CaO, then some other oxide or compound. In the area designated $2CaO.SiO_2$, this compound is the first to crystallize, and so on for all the areas. Some parts of the diagram representing certain kinds of mix-

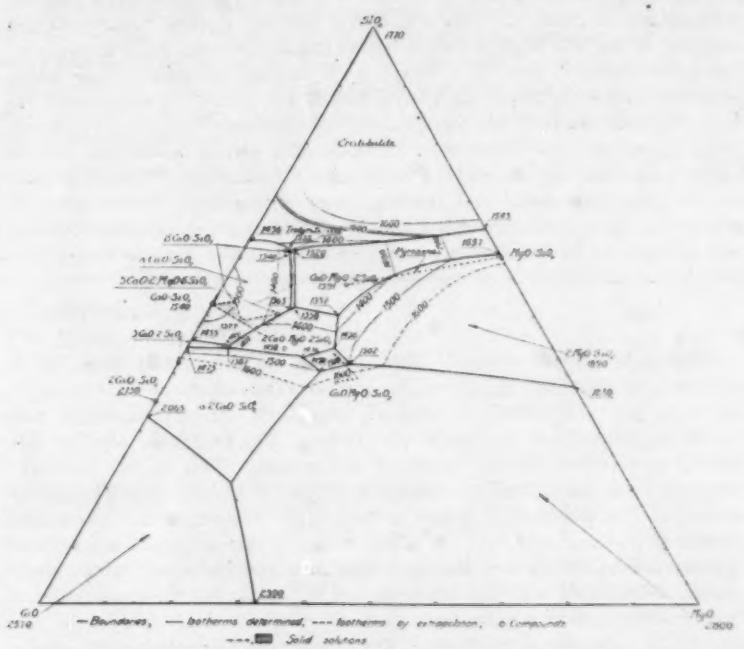

FIG. 1.—A concentration diagram upon which the isotherms showing the temperatures of complete melting of the various compositions are drawn. The diagram is on a wt. per cent basis.

tures and compounds are complicated by the fact of production of solid solutions, as for example, the pyroxenes which are mixtures of $CaO.MgO.2SiO_2$ and $MgO.SiO_2$. The system $CaO–MgO–SiO_2$ is the most complicated of the four systems in the series on account of the great number of solid solutions which may form. As indicated in the diagram, there are 14 crystalline phases (oxides, compounds, and solid solutions) found in this ternary system. There exist also 14 quintuple or invariant points at which three crystalline phases and a liquid can co-exist, and of these, six are true eutectics. These

quintuple points are the points of intersection of three boundary lines and when the temperature along each of the three lines falls as they approach the point of intersection the point is called a eutectic, the mixture having a lower temperature of complete crystallization than surrounding mixtures. The broken lines and the light full-lines in the diagram pass through points representing mixtures having like temperatures of complete melting. It is noted that a certain mixture represented in the upper left portion of the diagram and having a composition of 32% CaO, 7% MgO, 61% SiO_2 has a melting temperature of 1320° C, being the lowest melting eutectic mixture in the system. If the 7% MgO were left out of the mixture the melting temperature would be about 1500° C. It is such low melting mixtures as these which become effective as fluxes in pottery bodies and glazes. Comparisons are made between some of the compounds and solutions produced and those found in nature. In addition to 13 crystalline phases which are definite compounds there are described 5 series of solid solutions. Optical properties of these compounds and solutions were determined. While these investigations have been carried out mainly as studies of the formation of rocks and minerals in nature they are useful in studying the fundamental principles of the production of silicate products in the industries.

F. A. KIRKPATRICK.

Alkalies in cement clinker: Their relation to the setting time. B. F. ERDAHL. *Concrete, C. M. S.*, **15**, 17 (1919).—The nature of the alkalies in flue dust has been extensively studied, while little attention has been paid to the non-volatilized alkalies in the clinker. The remaining alkalies may have a great effect on the quality of the cement. This applies especially to plants using the Cottrell precipitation system for abating the dust nuisance and recovering the dust for clinker, potash, or for both purposes. Theoretical considerations indicate that the alkalies in the raw materials are entirely decomposed by the heat of the clinkering zone and the alkali vapors immediately recombined with the liberated SO_2 to form sulphuric compounds of higher volatilization temperatures than the original ones. SO_2 in the coal aids in the formation of sulphates. The amount of CO_2 present in the clinker is very small. Flue dust, clinker, and c. p. $CaCO_3$, each in ten g. amounts, were heated at 1050° C for 2 hrs., then at 1150° C for 30 mins. By considering the $CaCO_3$ determination as a blank, the dust was found to contain CO_2 equivalent to 0.06% K_2CO_3, and the clinker an amount equivalent to 0.03% K_2CO_3. It is possible that volatilized potash and soda recombine with the coal ash forming a silicate slag, which may remain undecomposed and come out with the clinker. However, there can hardly be any doubt that the greater part of the alkalies exist in the clinker as sulphates, some as plain K_2SO_4 and Na_2SO_4, and some perhaps as double salts of these, with lime or silica. In order to strengthen this belief, two representative clinkers were analyzed for water-soluble alkalies by boiling 12 hrs., and for total alkalies by the J. Lawrence Smith method. The results were as follows:

Sample No.	% total K_2O.	% water-soluble K_2O.	% total Na_2O.	% water-soluble Na_2O.
1	0.15	0.12	0.26	0.10
2	0.28	0.26	0.33	0.19

From this it is seen that the greater part of the alkalies in the clinker is composed of water-soluble compounds and that the K salts are more soluble than the Na salts. The most important effect of the alkalies in the cement is that of change in the time of set. Solutions of alkali sulphates, carbonates and silicates were prepared, ranging in strength from 1% to 5% of the anhydrous compounds. These solutions were added to a cement of good quality which had an initial set of 180 mins. and final set of 380 mins., by the Gilmore needle test. 22.5% of solution (by wt.) was added in all cases, the temperature of air and water was between 21° and 22° C and all pats were sound. The results are given in the following table:

Solution used.	% alkali by dry wt	Time of set. Minutes.	
		Initial.	Final.
Water	0	180	380
K_2SO_4	.225	150	300
	.675	135	260
	1.125	135	250
Na_2SO_4	.225	120	275
	.675	110	260
	1.125	90	230
K_2SiO_3	.225	150	370
	.675	125	310
	1.125	120	300
Na_2SiO_3	.225	160	335
	.675	125	300
	1.125	100	260
K_2CO_3	.225	65	260
	.450	11	150
	.675	7	20
	1.125	5	10
Na_2CO_3	.225	65	260
	.450	9	36
	.675	6	12
	1.125	5	12

The conclusions are as follows: (1) The alkalies exist in clinker and cement mainly as readily soluble K and Na sulphates, and as slowly water-soluble double sulphates of the alkalies and lime. (2) The smaller part of

the alkalies in clinker and cement exist as water-insoluble or very slightly soluble alkali slags (silicates), consisting chiefly of Na compounds. (3) Traces of K and Na carbonates may be present in clinker and cement, but hardly in amounts to affect their physical qualities. (4) The alkali sulphates and silicates have a somewhat quickening influence on the settling time of cement. The alkali sulphates are also detrimental to the free use of gypsum as a retarding agent, as a smaller amount must be added to keep within the specification of 2% SO_3. (5) The alkali carbonates are very dangerous to the setting qualities of cement but are not often found in large amounts. Alkalies do not have any determining effect on the soundness of cement.

F. A. KIRKPATRICK.

CERAMIC PATENTS.

G. E. MIDDLETON, *Abstractor.*

Process of molding lavatories. D. W. MCNEIL. U. S. 1,311,410, July 29, 1919. A removable core is used in molding the overflow passage in the back wall of the lavatory thus avoiding the necessity of applying the walls of this passage to the exterior of the bowl and affecting the adhesion by means of slip.

Process of separating mica from feldspar. G. J. BANCROFT. U. S. 1,310,939, July 22, 1919. Feldspar and mica are ground together and separated by washing, the feldspar being lighter than the mica.

Process of producing potassium hydrate from green sand. B. A. PEACOCK. U. S. 1,309,744, July 15, 1919. Glauconite or feldspar is heated for 15 or 30 minutes with KOH or K_2CO_3 to form a potassium zeolite which is very slightly soluble in water. To this zeolite, $Ca(OH)_2$ and water are added and the mixture boiled for an hour. The $Ca(OH)_2$ reacts with the small part of the zeolite which has gone into solution, precipitating a water-insoluble calcium zeolite and leaving KOH in solution.

Process of treating silicates containing potassium and aluminium. L. A. EBERHARDT, U. S. 1,310,413, July 22, 1919. Potassium and aluminium salts such as potash alum and aluminium sulphate are recovered from silicates containing potassium and aluminium. A finely divided mixture of sericite, feldspar or other potassium-aluminium silicates, fluorspar and gypsum, is calcined at a red heat in a rotary furnace for two hours. The calcined mixture is then treated with H_2SO_4 in sufficient amount to form the desired sulphates. The $K_2Al_2(SO_4)24H_2O$ and $Al_2(SO_4)_3$ are separated by evaporation.

Process of decomposing potassium silicates. S. R. SCHOLES. U. S. 1,312,053, August 5, 1919. Orthoclase feldspar, leucite, sericite, lepidolite, the micas or any other like potassium aluminium silicates may be treated and if only alumina and silica are the products sought, kaolin, sillimanite or

other aluminium silicates may be used. Equal parts of the silicate are mixed and fused with Na_2CO_3 or K_2CO_3. The resulting glass is pulverized, is then digested at about 160° C, corresponding to about 90 pounds steam pressure, for about two hours. It is then filtered and washed until free from alkalies. The washed precipitate consists of a compound containing alumina. The filtrate is treated with CO_2, the alkali metals being converted into carbonates from which the silica separates as a colloidal precipitate.

Process of decomposing natural silicates. B. A. PEACOCK. U. S. 1,310,770, July 22, 1919. Potassium-bearing silicates are decomposed with the aid of H_2SO_4. Feldspar, leucite, glauconite, etc., are mixed in finely divided condition with a magnesium-bearing silicate, such as serpentine or dunite, and sufficient H_2SO_4 added to convert substantially all the potassium and magnesium present into sulphates. This pasty mass is placed in a heavy masonry receptable 10–25 feet in depth called a "den," similar to a silo. The serpentine and dunite are attacked by the acid in the cold, the temperature of the mass being elevated to 150° C and the pressure in the den rising. The potassium-bearing silicates are then decomposed. After 24 to 48 hours a double sulphate of potassium and magnesium may be recovered. It is treated with $CaCl_2$ to form a double chloride and this is digested with slaked dolomite resulting in $CaCl_2$ and KCl in solution and precipitation of all magnesium as hydroxide. The KCl is obtained by evaporation.

Process of purifying aluminous materials. O. HUTCHINS. 1,310,342, July 15, 1919. This process relates to the production of an aluminous abrasive material of relative high purity, containing not over 1% each of Fe_2O_3, TiO_2 and SiO_2, and consists in fusing aluminous materials such as bauxite, in the presence of carbon insufficient in amount to reduce all the Fe_2O_3, TiO_2 and SiO_2 contained therein, separating the aluminous product from the reduced impurities and re-fusing the product in the presence of sufficient carbon to cause a further reduction of the above oxides.

Abrasive Wheel. H. R. POWER. U. S. 1,310,291, July 15, 1919. The voids of an abrasive wheel having a ceramic bond are filled with polymerized benzofuran or paracoumarone. This substance has a relatively high melting point, and a grinding temperature of 90° C may be reached before it begins to flow.

U. S. 1,310,292 discloses the use of a mixture of paraffin wax and paracoumarone for impregnating porous abrasive wheels having a ceramic bond.

Abrasive Wheel. H. C. MARTIN. U. S. 1,310,360, July 15, 1919. An abrasive wheel having a silicate bond the voids of which are filled with a chlorin derivative of naphthalene such as Halowax, $C_{10}H_4C_{14}$.

Lining for acid pots. C. F. CURTIS. U. S. 1,311,051, July 22, 1919. An acid-resisting cement is said to be made from the following ingredients: sawdust 30%, portland cement 30%, whiting 10%, waste residue of pyrites furnaces 30%.

Flowing molten glass. J. WHITTEMORE. U. S. 1,310,225, July 15, 1919. This invention relates to the method of segregating molten glass into individual mold charges or gobs in which the glass is periodically severed by a mechanical shear as it is discharged vertically downward from the furnace in the form of a column. When a gob has been severed the cutter is immediately withdrawn and the glass exudes in the form of a heavy stream. At the same time a heating cup swings beneath the flow opening and up into engagement with the bottom plate of the furnace. This cup is provided with a refractory lining heated by an electric coil, the heat serving to reheat the chilled, cut end of the glass and eliminate the shear marks. The entire surface of the glass column is heated. The glass is prevented from actual contact with the walls of the cup by means of heated compressed air introduced through perforations in the cup. After sufficient heating the cup is swung downward and to one side and the gob is sheared and dropped into the mold.

Method and apparatus for manufacturing window-glass cylinders. CAMPBELL. U. S. 1,312,305, August 5, 1919. Variations in the surface tension of glass in the pot cause the cylinder to move away from the center and into contact with the side of the pot. This may be avoided by leveling and unleveling the pot either before or during the draw which regulates the cooling and equalizes the temperature of the glass in the different parts of the pot.

Glass apparatus. C. DONALDSON, J. J. BLOXAM and J. K. BROOKS. U. S. 1,311,804, July 29, 1919. A support for glass cylinders after drawing and during the capping operation. This support or horse is provided with a reheater for the bait which is rendered automatically active when the bait is placed upon it.

Glass-working apparatus and process. F. L. O. WADSWORTH. U. S. 1,311,474, July 29, 1919. When molten glass is allowed to flow downward from a melting furnace to a mold it becomes externally chilled. If, when the flowing column of glass is cut, it is cut too near the discharge orifice, the chilled walls and the end chilled by the cutting prevent the continued free flowing of the glass and cause delay. If, on the other hand, the column is cut too far from the discharge orifice the result is an immediate resumption of the flow before the second mold is in readiness. This is regulated by the use of artificial chilling means employing as cooling media steam or compressed air.

Method of and apparatus for gathering glass by suction. E. ROIRANT. U. S. 1,311,249, July 29, 1919. Ordinarily in gathering glass by suction the lower portion of the gathering means causes a cooling of the glass, by reason of the metallic contact of the device with the glass, with the result that after several successive gathering operations at the same place the glass can no longer be used. This invention is said to obviate this difficulty. A float of

silica bricks rests upon the surface of the molten glass. The suction gathering means is brought with its lower end in contact with a cavity in the float at the same time slightly submerging the latter and causing the glass to rise in the lower part of the gathering means. Gathering is then effected by the use of suction.

Combined glass machine. G. A. SHIELDS. U. S. 1,310,451, July 22, 1919. Plate or sheet glass is flattened and scored while in molten condition as it emerges from the delivery or discharge end of the tank-furnace and the thickness of the glass is determined by an adjustable gate governing the discharge of the molten glass. The transparency of the glass is regulated by varying the vertical drop from the furnace, the longer the drop, the more transparent the glass.

Glass drawing apparatus. H. K. HITCHCOCK. U. S. 1,309,942, July 15, 1919. This apparatus is designed particularly for drawing glass cylinders. The motive power for drawing the cylinder is also utilized in swinging the take-down frame; at the end of the draw the power is automatically shifted from the drawing mechanism to the take-down apparatus. The air supply is taken care of in a simple and effective manner and provision is made for guiding and steadying the drawing mechanism.

Apparatus for handling glassware. R. LAFRANCE. U. S. 1,310,194, July 15, 1919. A switching device receives bottles as they are delivered from a glass-forming machine and directs them alternately to setting-up devices by which they are placed in an upright position to be conveyed to an annealing oven or lehr. It is said that single setting-up devices have been found incapable of sufficient speed to enable them to be used with some automatic bottle machines. The present invention avoids this difficulty by providing two setting-up devices in combination with the oscillating switch.

Horse for glass cylinders. J. H. CAMPBELL. U. S. 1,312,306, August 5, 1919. The several saddles of this horse are so arranged that pressure on one is transmitted to the others, thus evenly distributing the weight of the cylinder. This is accomplished by mounting the shanks of the saddles upon a common balanced lever, fulcrumed and spring-supported at its center.

Kiln. F. MUNHOLLON. U. S. 1,311,286, July 29, 1919. The object of this invention is to distribute evenly and thoroughly utilize the heat in a down-draft kiln. Alternating with the bag-walls along the inner wall of the kiln are a series of vertical flues open at both ends and affording a connection between the space beneath the checker floor and the interior of the kiln adjacent to the crown. In each of these flues is a vertically directed nozzle designed to inject compressed air or steam thereinto. The pressure of the fluid used is sufficient to effect an aspirator action with the result that hot products of combustion which have passed down through the checker floor are whirled upward through the vertical flue and debouched against the crown of the kiln.

Enameling-kiln. G. H. BENJAMIN. U. S. 1,311,487, July 29, 1919. The bath tubs or other ware to be enameled are placed upon trucks and passed successively through a preliminary heating chamber, a coating or enameling chamber and a secondary heating chamber, the temperature gradually increasing in the preliminary heating chamber and gradually decreasing in the secondary. During the enameling proper, heavy doors shut off all communication between the coating and heating chambers so that workmen may enter and sprinkle on the enamel without any considerable physical discomfort.

Process for burning brick. F. B. LAMBERT. U. S. 1,311,978, August 5, 1919. The kiln used in this process is a temporary clamp or scove kiln. The noteworthy feature of the process is the so-called double use of heat. The firing is started using steam and oil burners, the supply of fuel being gradually increased until the arches are filled with flame from end to end. Then follows a period of intense firing resulting in an isothermal zone of incandescence extending throughout the kiln and just above the arches. When the proper heat condition has been attained as indicated by the settle, the firing is stopped and blasts of steam shot into the arches. The result of this treatment is to raise the isothermal zone of incandescence slowly up through the unburned brick. After twenty-four hours the steam is discontinued, and the natural draft allowed to complete the upward movement of the hot zone. Excellent results are said to have been accomplished by this method in the burning of Chicago hard-pan bricks.

Gas burner for kilns. R. H. MCELROY. U. S. 1,311,132, July 22, 1919. This burner consists of an elongated rectangular shell the inner end of which has a downwardly and forwardly slanting air passage which receives air through the top of the burner. Below the air passage there is a gas passage which receives gas through the bottom of the burner. This burner is said to give a long flame, obviating damage to the kiln due to localization of the heat.

Brick-machine. A. MALINOVSKY. U. S. 1,310,953, July 22, 1919. A dry-press brick-machine in which the end and edge faces of the bricks are stippled by means of stipple plates acting synchronously with the pressing rams.

Concrete composition. A. A. BENNETT. U. S. 1,310,520, July 22, 1919. A hard, strong concrete impermeable to water is said to be made from the following: Portland cement 1 part, aggregate consisting of conglomerate copper stamp sand 2 parts. The conglomerate runs from $1/4''$ in size to that which will pass through a screen of 200 wires to the inch and its composition is: SiO_2 60%, Al_2O_3 16%, Fe_2O_3 10%, CaO 3.5%, MgO 1.6%, Na_2O and K_2O 6%, metallic copper 0.6%.

Note.—Copies of these patents may be obtained for five cents each by addressing the "Commissioner of Patents, Washington, D. C."

ACTIVITIES OF THE SOCIETY.

Meeting of the Refractories Division.

Niagara Falls, N. Y., August 4, 1919.

The meeting was called to order by the Chairman immediately after the dinner given by the Society. There were eighteen persons present.

Attention was called to the necessity of securing papers for the next annual meeting. Upon canvassing the audience, Messrs. Harvey, McDowell, Babcock, Howe, Klein, Shaw and Ross agreed to submit contributions.

The urgency of the situation with reference to the refractories used in the glass industry was then discussed. A motion to create a sub-committee on Glass Refractories was adopted. This Committee is to be instructed to coöperate with the Glass Division in every way possible.

A general discussion took place on the subject of research topics having a direct economic bearing. Among the problems brought out were the following: Sagger compositions; thermal expansion; effect of weathering; microstructure; critical spalling temperatures; kiln design; thermal conductivity; relation between size of specimen and spalling effect, dolomite brick, cements, coke oven insulation, and steam-pressed vertical lime-kiln brick. As a result of this discussion, motions to create two additional sub-committees, one on sagger compositions and one on microstructure, were seconded and carried.

It was finally voted that a monthly letter be issued by the Committee to its membership, keeping it informed concerning matters of importance and interest. The fund allotted by the Society to the Division is to be used for this purpose at first. Later it might be possible to enlarge the monthly letter to a printed pamphlet, supported by regular contributions from the membership of the Division.

RAYMOND M. HOWE,
Secretary.

AMERICAN CERAMIC SOCIETY.

Acquisition of New Members during September, 1919.

Associate.

Berkey, Paul L., Secretary-Treasurer and Plant Superintendent, Lava Crucible Company, Pittsburgh, Pa.

Chamberlain, C. H., Taylor Instrument Companies, Rochester, N. Y.

Dixon, Henry L., President and General Manager, H. L. Dixon Company, Pittsburgh, Pa.

Gleason, Marshall W., President and General Manager, Gleason-Tiebout Glass Company, Brooklyn, N. Y.

Jewett, Fred E., General Superintendent, Ball Brothers Glass Manufacturing Company, Muncie, Ind.

Lawton, Lewis H., Secretary and General Manager, Jonathan Bartley Crucible Company, Trenton, N. J.

Lippert, Charles G., Assistant Factory Superintendent, Schram Glass Company, Hillsboro, Illinois.

Moss, Lester M., Superintendent, Harrison Bulb Works of General Electric Company, Harrison, N. J.

Navias, Louis, Chemist, Bausch & Lomb Optical Company, Rochester, N. Y.

Pritchard, Geo. A., Vice-President, Buckman & Pritchard, Inc., 165 Broadway, New York City.

Rogers, Jas. B., Experimental Engineer, 6231 St. Lawrence Ave., Chicago, Illinois.

Rupp, Edwin M., 714 Lincoln Avenue, Middletown, Ohio.

Scott, David H., Ball Brothers Glass Manufacturing Company, Muncie, Ind.

Solon, Leon V., Art Director, American Encaustic Tiling Company, 454 Riverside Drive, New York City.

Wherry, Jas. B., Research Chemist, Refinite Company, Omaha, Neb.

Corporation.

H. L. Dixon Company, Pittsburgh, Pa.

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¶ Actual records were kept for 365 days of the burning of 9-inch, high-grade, refractory brick in one continuous tunnel kiln and in seven 30-foot round kilns, during which time 5,110,000 brick were burned in the tunnel kiln as against 5,040,000 in the seven round kilns.

¶ But this isn't all—the actual labor saving amounted to $5,808.00. Taking into consideration the necessary items of depreciation, interest on plant, maintenance and repairs, the average yearly cost for burning 1,000 brick in the continuous tunnel kiln system was $2.95 as against $6.20 in the round kilns.

¶ If you are really interested in the greater efficiency of burning, you will let us tell you more about the actual accomplishments of

The Didier-March Continuous Railroad Tunnel Kiln

Didier-March Company

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Contractors *Manufacturers of Refractories* *Engineers*

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Second:—This twin tunnel kiln allows a greater utilization of the fuel than a single tunnel kiln, as the heat from cooling ware is used for water-smoking the incoming ware.

Third:—This kiln allows an absolute and positive control of the firing zone, and in the firing zone a reducing or oxidizing condition can be maintained at will.

Fourth:—The cooling of the ware as well as the water-smoking and pre-heating in this kiln are absolutely automatic. It is impossible to get the receiving end of the tunnel too hot.

Fifth:—This kiln will save about 50% on labor and from 65% to 75% on fuel as compared with periodic kilns. Burning time is cut down by ⅓ to ¼. Where saggers are used, they will last twice as long.

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In order to increase the stock of certain volumes of the Transactions of the American Ceramic Society, the Secretary of the Society has been authorized by the Board of Trustees to purchase a limited number of copies of Volumes II, V, IX, X, XII, and XIX, at five dollars each. Members or former members who are willing to dispose of their copies please communicate with

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Apr.	13	1915..	3
July	17	1916..	1
Dec.	7	1916..	1
Mar.	31	1917..	1
May	19	1917..	4
June	23	1917..	1
Oct.	26	1917..	3
Nov.	1	1917..	4
June	29	1918..	9

Beth. Steel Co.

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Oct.	15	1913..	1
Nov	1	1913..	1
May	8	1914..	1
May	14	1914..	3
May	6	1915..	1
Dec.	14	1915..	2
Nov.	7	1916..	3
Jan.	4	1917..	1

Beth. Steel Co.

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Aug.	14	1917..	1
Dec.	3	1917..	52
May	24	1918..	1
July	15	1918..	2
April	9	1918..	2
May	21	1918..	2
July	20	1918..	1
Jan.	22	1918..	5
Sept.	10	1918..	1
Oct.	4	1918..	1

Halcomb Steel Co.

Mar.	13	1916..	1
Oct.	27	1916..	1
Oct.	29	1918..	2
Dec.	27	1918..	1

Watertown Arsn'l

Sept.	23	1912..	1
June	30	1914..	1
July	1	1914..	1
Mar.	24	1916..	1
May	8	1917..	1

Watertown Arsn'l

June	4	1917..	1
June	25	1917..	1
Oct.	15	1917..	5
Oct.	23	1917..	18
Oct.	27	1917..	6
Jan.	5	1918..	1
Dec.	2	1918..	1

Packard Motor Car Co.

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May	13	1914..	1
June	14	1914..	1
June	26	1915..	1
June	28	1915..	7
Aug.	16	1915..	1
Feb.	25	1916..	4
Feb.	3	1917..	1
Dec.	1	1917..	2
Jan.	11	1917..	14
Mar.	9	1917..	1
Dec.	16	1918..	4
April	22	1919..	4

DuPont Co.

Aug.	23	1915..	5
Oct.	15	1915..	2
Oct.	27	1916..	1
Oct.	28	1916..	1
Oct.	29	1916..	1
Jan.	5	1916..	1
Jan.	8	1916..	2
Jan.	8	1917..	1
Mar.	25	1917..	1
July	24	1917..	1
July	26	1917..	2
Nov.	11	1917..	1
Feb.	19	1918..	1
Mar.	28	1918..	1
Oct.	12	1918..	1
April	4	1919..	1

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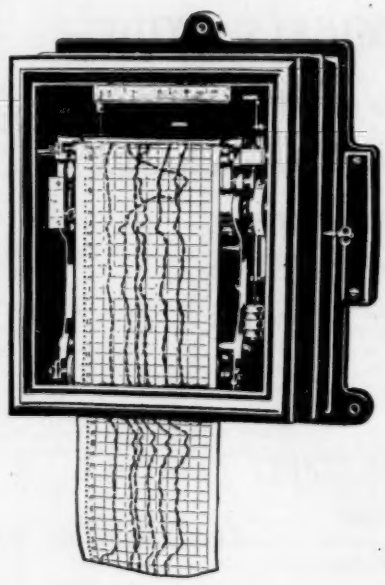

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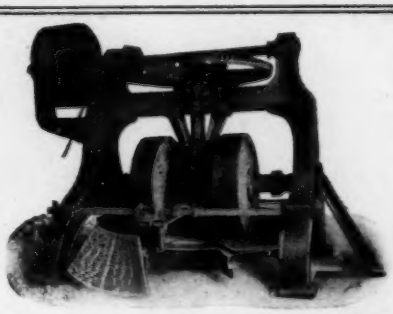

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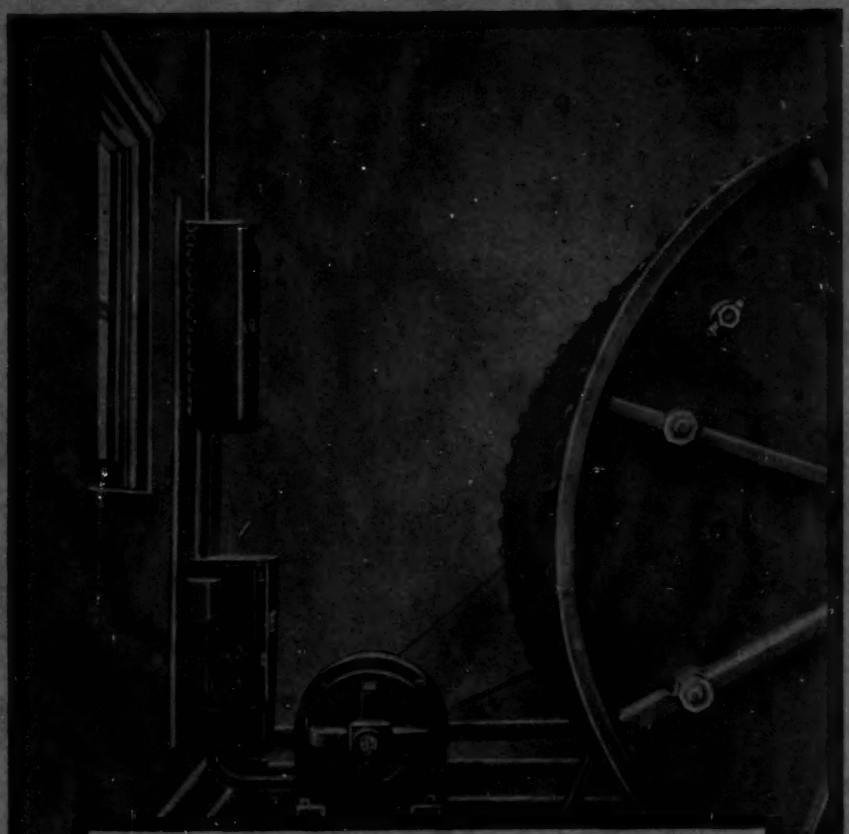

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General Electric Company

General Offices: Schenectady, N. Y. Sales offices in all large cities